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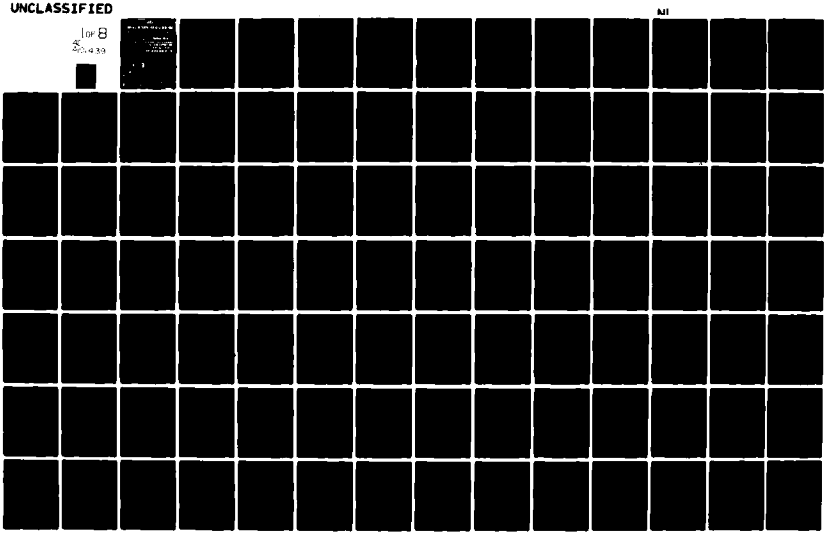

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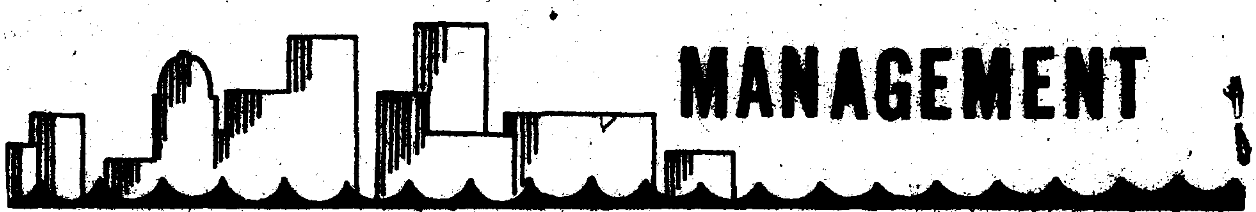

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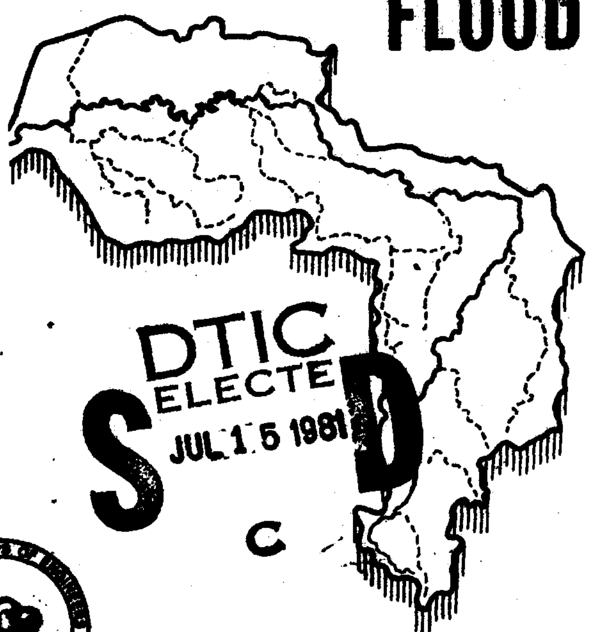

TONAWANDA CREEK WATERSHED

FINAL FEASIBILITY REPORT

U.S.ARMY
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APPENDICES

December 1980

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The purpose of the Tonawanda Creek Watershed, N.Y., Flood Management Feasibility Study is to develop and evaluate alternative plans to provide for flood and flood-related management needs in the Tonawanda Creek Watershed. In accordance with Corps policy, this study has been accomplished in two phases. During the first phase, all significant flood and flood-related management needs in the Tonawanda Creek Watershed were identified. Then measures to provide for these needs were identified. Then measures to provide for these

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for those needs were identified and appraised. These measures were considered alone, and in combination, in development of alternate plans. The alternate plans were then evaluated and those which appeared viable were recommended for further study. During the second phase, those plans Recommended for further study, and alternate plans introduced following completion of the first phase, were evaluated, and the optimum plan has been recommended for implementation. This report presents the findings of the second phase of study.

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED.
INTERIM FLOOD MANAGEMENT STUDY.

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APPENDIX A

HYDROLOGY

AND

HYDRAULICS

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

FOREWORD

This appendix has been divided into sections to present the results of Generalized Hydrologic Investigations applicable to the entire Tonawanda Creek watershed and investigations at specific locations. Section A1 contains information relative to Generalized Hydrologic Investigations. Sections A2 through A5 contain information relative to investigations for the Considered Reservoirs, Lower Tonawanda Creek watershed, Upper Tonawanda Creek watershed, and Hydraulic Design, respectively. Section A6 and A7 address respectively the comments in the Memorandum of Understanding, 9 February 1977, and 24 April 1980, NCDPD-PF which are applicable to this appendix.

At a meeting in OCE on 14 December 1976, suggested revisions to the 1976 Tonawanda Creek FFR were presented with the understanding that incorporation of these comments would satisfy present OCE policy in having a greater level of hydrology. It was stated that with these comments in the authorizing document, the recommendation should be for authorization of construction with a minimum of Phase 1 activities. Since that time, the study has been redone. Concern for the functional adequacy of the project and the benefits claimed have been mitigated. The regional duration-frequency investigations were updated and improved. Field surveys during high water proved invaluable in determining the path of the water in the lower watershed. Diversion discharge rating curves were developed allowing hydrograph routing and combining simulation to the confluence with Ransom Creek. Surveys in the proposed Lower Reservoir area revealed the path of the water in that area (Plate A2) and the impracticality of the 1976 report location of the emergency spillway.

The operation policy originally proposed was scrutinized and revised with a new operation plan developed. For floods with an annual return period of less than 10 years, the reservoirs are operated to impound floodwaters while making releases such that the routed release combined with local inflow does not exceed damaging discharges at downstream damage centers (forecasting.) For 10-year floods and greater, the reservoirs are operated as flood attenuators which either limit the release to a specific discharge relative to downstream channel capacities or in reducing the discharge through storage of floodwaters (nonforecasting.) Damage reduction is greatest for the more frequent floods. Benefits claimed are conservative as the analysis accounts for a misoperation (when one has to decide whether or not to forecast) during the 10-year balanced flood and that there is a considerable quantity of water in the balanced hydrographs.

At a meeting 18 and 19 March 1980 between the Buffalo District and North Central Division further revisions to the 1979 report were suggested. The major revisions comprise further clarification and enhancement of the hydrologic and hydraulic engineering methods used in the study. The suggestions have been incorporated and this appendix represents the results of that effort.

Recognition is extended to:

Bradford S. Price, Chief, Hydrologic Investigations Section, Corps of Engineers
Michael C. Mohr, Hydraulic Engineer, Corps of Engineers
Lawrence J. Sherman, Hydraulic Engineer, Corps of Engineers

along with engineer trainees, hydraulic technicians, and personnel in the Word Processing Branch for their support and contributions to this appendix. Assistance from USGS and NWS personnel is acknowledged for their time and effort in providing necessary hydrologic data.

CAVEAT

The results of the hydrologic and hydraulic engineering studies presented herein indicate that a viable and functionally adequate plan exists for reducing flooding in the Tonawanda Watershed. These studies, based upon the best available data and the use of available and appropriate techniques of analysis, were performed continuously and painstakingly throughout the previous 5 years. It is hoped, therefore, that reviewers take a sufficient amount of time to read and understand the results presented in this report.

BUFFALO METROPOLITAN AREA, NY
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APPENDIX A

A1. GENERALIZED HYDROLOGIC INVESTIGATIONS

A1.1 Description of Tonawanda Creek Watershed

The Tonawanda Creek Watershed encompases an area of 648 square miles, wholly in Western New York State. Plate A1 shows the location of the watershed within the State and the numerous tributary drainage areas within the Tonawanda Creek Watershed. Tonawanda Creek flows from its source in the Cattaraugus Hills in Wyoming County, through deep valleys with steep slopes, northward for approximately 22 miles to Attica. From there the creek passes through flat bottom land, with limited channel capacity, to Batavia. Turning westward at Batavia, the creek winds its course through more level terrain. The channel is often insufficient; the creek flows sluggishly and often floods extensively during periods of high flow. Ledge-Murder Creek is the principal tributary emptying into Tonawanda Creek between Batavia and Rapids. Below river-mile 11.2, Tonawanda Creek forms a portion of the New York State Barge Canal and continues to the Niagara River. This reach, as part of the Barge Canal system, has an improved channel with flood discharges usually flowing well within the channel. A large portion of the lower watershed drains within this reach. Mud Creek enters immediately upstream of the Barge Canal confluence. Ransom-Black-Gott Creek enters just below this confluence. Ellicott and Bull Creeks join the mainstream near Tonawanda's confluence with the Niagara River. Flood management needs for Ellicott and Bull Creeks are independent of those in the remainder of the watershed and studies of those needs have been accomplished separately. Further discussion on the character of the watershed may be found in the Main Report, Section II. Table A1.1 presents a tabulation of stream slopes and drainage areas for Tonawanda Creek and its tributaries.

A1.2 Climatology

There have been 12 climatological stations located in or adjacent to the Tonawanda Creek Watershed as shown on Plate A1. Of these 12, only eight are still in operation, including the Weather Bureau First-Order station at the Buffalo International Airport. The average annual precipitation for the 12 stations (through 1966) is 36.92 inches. Monthly averages vary from a minimum of 2.53 inches in February to a maximum of 3.33 inches in May.

A1.3 The average annual snowfall for the 12 stations (through 1966) is 82.3 inches. The highest average monthly snowfall is 22.4 inches in January at Arcade, NY.

A1.4 The average annual temperature for 10 of the stations (through 1966) is 46.9 degrees Fahrenheit. The maximum average monthly temperature is 69.2 degrees in July, while the minimum is 24.2 degrees in January.

A1.5 Flood Producing Factors

According to records, most of the floods in the Tonawanda Creek Watershed have been caused by melting snow with moderate amounts of rainfall rather

Table A1.1 - Stream Slopes and Drainage Areas, Tonawanda Creek and Tributaries

Location	Distance Above Niagara River River Miles	Slope Feet/Mile	Drainage Area Square Miles
Tonawanda Creek at Niagara River	0	4.75	648
Tonawanda Creek at Ellicott Creek	.3	4.75	647
Ellicott Creek at Mouth		5.49	110
Tonawanda Creek at Bull Creek	4.8	4.79	537
Bull Creek at Mouth		6.91	26.9
Tonawanda Creek at Ransom Creek	9.8	5.38	500
Ransom Creek at Mouth		2.76	60
Tonawanda Creek at Mud Creek	13.0	5.68	414
Mud Creek at Mouth		2.16	41.1
Tonawanda Creek at Rapids Gage	18.5	5.76	358
Tonawanda Creek at Beeman Creek	23.3	6.18	356
Beeman Creek at Mouth		10.83	15.4
Tonawanda Creek at Ledge Creek	33.0	7.16	318
Ledge Creek at Mouth		29.0	74.2
Tonawanda Creek at Alabama Gage	41.5	7.92	231

Table A1.1 - Stream Slopes and Drainage Areas (Cont'd)
Tonawanda Creek and Tributaries

Location	Distance Above Niagara River River Miles	Slope Feet/Mile	Drainage Area Square Miles
Tonawanda Creek at Bowen Creek	56.8	7.92	200
Bowen Creek at Mouth		29.8	15.7
Tonawanda Creek at Batavia Gage	63.8	7.92	171
Tonawanda Creek at Little Tonawanda Creek	68.8	9.59	151
Little Tonawanda at Mouth		36.2	38
Tonawanda Creek at Alexander	78.0	18.3	102
Tonawanda Creek at Attica	82.0	24.0	81

than rainfall alone. The magnitude of a snowmelt flood is highly dependent upon the amount of snowpack, and the magnitude and temporal variation of temperature. During the March 1960 flood, only 0.2 inches of rain fell over the basin. With temperatures reaching 66°F, the 5.2 inches of water equivalent snow melted rapidly resulting in the flood of record. During the March 1978 flood, however, with maximum daily temperatures reaching only 45°F, the 2.4 inches of water equivalent of snow melted slowly with minimal flooding. The orientation of the watershed with respect to the usual direction of travel of frontal systems in this area also influences the effect of rainfall on runoff. Tonawanda Creek below Batavia flows generally westward and frontal system direction is typically from west to east. An examination of streamflow records for the Tonawanda Creek at Alabama gage for the period 1922 through 1977 revealed 84 flows above the bankful stage of 12 feet. Of these, 75 occurred during December through April, with nine occurring during the remainder of the year.

A1.6 Maximum Known Floods

Flooding in the Tonawanda Creek Watershed has been recorded as early as March 1904. As mentioned in paragraph A1.5, most floods have been caused by melting snow with moderate amounts of rainfall. In some years, two or three floods have been recorded from successive snowmelts. The most damaging Tonawanda Creek flood of record at Batavia occurred on 31 March 1960, with flooded outlines shown on Plates A2a-A2c for existing and improved (Batavia Reservoir Compound) conditions. Field surveys for highwater marks and flood fringe location during and after the March-April 1960 flood supplied the necessary information to draw the flooded area maps. Flow direction and the discharge under existing and improved conditions are also shown along with the approximate range of channel capacities in the reach. Further description of this flood may be found in paragraph A1.44. The most recent flood occurred in March 1979. A comparison of hydrologic data for several major floods on Tonawanda Creek is shown in Table A1.2. It should be noted that the September 1977 flood is the summertime flood of record, with further discussion to be found in paragraph A1.45. Table A1.3a lists discharge data at gaging stations on Tonawanda Creek for eight floods of record.

A1.7 Runoff and Streamflow Data

The streamflow data for the hydrologic studies of this report were obtained from the records of the United States Geological Survey (U.S.G.S.), New York State Department of Public Works, and city of Batavia for gages on the streams listed in Table A1.3b. Gaging station locations are shown on Plate A1.

A1.8 Channel Capacities for Tonawanda Creek

A brief description of the watershed and the character of Tonawanda Creek is presented in A1.1. Backwater calculations were not performed which made it necessary to infer the range of channel capacity for a reach from a study of stream gage records and field observations. In all cases, estimates were conservatively made in order to not overstate the channel capacities and thereby overstate the benefits attributable to operation of considered

reservoirs. The stream gage locations are shown on Plate A1. Damage reaches were delineated from the mouth to Attica, NY, and are shown on Plates A1a through A1c.

A1.9 In Table A1.4 the channel capacities for Tonawanda Creek are presented. Tonawanda Creek has the largest capacity near the mouth (Reaches T-1 thru T-3). Channel improvements in this portion of the creek were completed before the turn of the century as part of the Barge Canal System. Depending upon the Niagara River stage the channel capacity will range between 10,000-12,000 cfs. From the confluence with the Barge Canal to River Mile 28.0 (Reaches T-4 thru T-7) the channel capacity is limited to 4,000-6,000 cfs. The rating curve at the Rapids gage was used as the basis for this estimate along with field observations during recent flooding. Although the banks are steep in many sections, the capacity is limited due to the extremely mild slope and meandering channel. From there to Alabama (Reaches T-8 thru T-10) the channel meanders considerably with a bank-full capacity of 3,500-4,500 cfs. Ledge Creek enters in this section and shall be used as a downsteam control point for the proposed Batavia Reservoir Compound. The range of channel capacity was again determined utilizing the stage-discharge relation at the Alabama gage and field observations during flooding.

A1.10 Discharge measurements and highwater marks obtained by Buffalo District personnel allowed channel capacity estimates to be made for Ransom-Black Creek and Mud Creek. Limited backwater calculations utilizing cross-section data to be used in a future FIS study substantiated the Mud Creek estimate.

A1.11 From Alabama to Bushville (Reaches T-11 & T-12) there is a 3,200-4,200 cfs range of channel capacity. The slope in this portion of the creek is generally mild except near Indian Falls where Tonawanda Creek flows from the Erie Plain to the Huron Plain with a resulting 120-foot drop in elevation in 1.8 river miles. Within the city of Batavia (Reaches B-1 thru B-5) the Corps of Engineers channel improvement project provides 6,000 cfs channel capacity. This project provided for widening of the creek channel from a point three-quarters of a mile west of the city line of Batavia to the municipal dam in Batavia. Bank protection was provided between Oak and Walnut Streets along with minor channel clearing above the Municipal dam to the Lehigh Valley Railroad bridge. The project was completed in 1956.

A1.12 The reach betwen Batavia and Alexander has a very mild slope and the channel has many bends which frequently causes debris jams to occur. A slope area calculation coupled with field observations revealed a 2,000 cfs channel capacity. Above Alexander the slope of the creek increases as the Cattaraugus hills are approached. The channel capacity increases partly because of the increased slope to a range of 3,000-5,000 cfs as indicated by discharge measurements at the USGS Attica gage.

A1.13 Table A1.4 presents ranges of channel capacities for Tonawanda Creek reaches.

Table A1.2 - Hydrologic Data for Major Floods by Tonawanda Creek at Batavia

Year	Date	Peak Discharge at Batavia, cfs	Rainfall Inches	Runoff Inches	Snow on Ground, Inches	Temp °F Max.	Temp °F Min.
1902	6 July	5,350 (1)	4.2	(2)	0	(2)	(2)
1916	28 March	7,050 (1)	0.4	(2)	(2)	58	40
1942	17 March	6,000 (1)	1.5	(2)	(2)	59	33
1956	7 March	6,480	2.5	1.9	1-2	46	22
1957	23 January	6,090	1.8	2.1	12-18	55	12
1959	22 January	5,230	1.5	1.7	12-18	52	12
1960	31 March	7,200	0.2	3.3	23 (3)	61	33
1977	25 September	5,120	7.7	5.5	0	69	56
1978	22 March	3,800	0.6	3.6	15 (4)	45	31
1979	5 March	5,570	0.3	3.0	11-18 (5)	52	35

(1) Corps of Engineers estimate based on highwater marks and backwater computations.

(2) Unknown.

(3) Average value from snow survey made by Corps of Engineers. Water content of snow was 5.2 inches.

(4) U.S.G.S. New York Cooperative Snow Survey. March 13-15, 1978.

(5) Based upon NWS records and USGS New York Cooperative Snow Survey taken 5-7 February 1978 and 5-7 March 1978.

Table A1.3a - Recorded Peak Discharges for Notable Floods in the Tonawanda and Little Tonawanda Creek Watersheds

Gage Location	Drainage Area sq. mi.	March 1942 cfs	March 1942 cfs/sq. mi.	March 1956 cfs	March 1956 sq. mi.	Jan. 1957 cfs	Jan. 1957 cfs/sq. mi.	Jan 1959 cfs	Jan 1959 cfs/sq. mi.
Linden	22.1	2,130	97	2,700	122	1,500	68	1,630	74
Batavia	171.0	6,000	35	6,480	38	6,090	35	5,230	30
Alabama (Hopkins Rd)	231.0	6,860	30	6,850	30	6,180	27	9,000(1)	39
Rapids (2)	358.0	-	-	5,090	14	5,210	15	4,450	12
(3)		-	-	7,780	22	7,790	22	6,700	19

(1) This discharge was determined by the U.S.G.S. from an ice-affected stage.

(2) Does not include flow which enters Mud and Black Creek upstream from the gage as discussed in Appendix A.

(3) Includes flow to Black and Mud Creek.

Table A1.3a - Recorded Peak Discharges for Notable Floods in the Tonawanda and Little Tonawanda Creek Watersheds (Cont'd)

Gage Location	Drainage Area sq. mi.	March 1960 cfs	March 1960 cfs/sq. mi.	September 1977 cfs	September 1977 sq. mi.	March 1978 cfs	March 1978 cfs/sq. mi.	March 1979 cfs	March 1979 cfs/sq. mi.
Attica	82	-	-	-	-	1,380	17	-	-
Linden	22.1	1,830	85	-	-	631	29	913	42
Batavia	171.0	7,200	42	5,120	30	3,620	22	5,570	33
Alabama (Hopkins Rd)	231.0	7,980	35	5,020	22	3,680	16	6,710	29
Rapids (2)	358.0	6,280	18	-	-	5,100	14	5,500	15
(3)		12,380	35	-	-	7,200	20	9,050	25

(1) This discharge was determined by the U.S.G.S. from an ice-affected stage.

(2) Does not include flow which enters Mud and Black Creek upstream from the gage as discussed in Appendix A1.

(3) Includes flow to Black and Mud Creek.

Table A1.3b - Maximum Known Peak Discharges at USGS Gaging Stations In and Around the Tonawanda Creek Watershed

Gaging Station	D.A.	Period of Record	Date	Peak Discharge cfs
Little Tonawanda at Linden	22.1	1912-1968 1978-present	7 March 1956	2,700
Cayuga Creek nr. Lancaster	94.9	1938-1968 1971-present	23 June 1972	8,800
Cazenovia Creek at Ebenezer	134.0	1940-present	1 March 1955	13,500
Buffalo Creek at Gardenville	144.0	1938-present	1 March 1955	13,000
Cattaraugus Creek at Gowanda	432.0	1939-present	7 March 1956	34,600
Oatka Creek at Warsaw	41.9	1963-present	23 June 1972	4,010
Ellicott Cr. nr. Williamsville	72.4 77.6	1955-1972 (1) 1972-present	31 March 1960	4,860

(1) Gage moved to U. S. Sheridan Drive.

Table A1.3b - Maximum Known Peak Discharges at USGS Gaging Stations In and Around the Tonawanda Creek Watershed (Cont'd)

Gaging Station	D.A.	Period of Record	Date	Peak Discharge cfs
Tonawanda Creek at Attica	82.0	1978-present	21 March 1978	2,107
Tonawanda Creek at Batavia	171.0	1929-1944 (2) 1944-present	31 March 1960	7,200
Tonawanda Creek at Alabama	231.0	1922-1955 (3) 1955-present	29 January 1959	9,000 (4)
Tonawanda Creek at Rapids	351.0	1955-1965 1978-present	1 April 1960	12,380 (5)
Black Creek at Swormville	2.8	1978-present	25 March 1978	8.82 (6)
Genesee River at Jones Bridge	1,419.	1910-present (7)	17 May 1916	55,100
Genesee River at Rochester	2,457.	1909-present (7)	30 March 1916	48,300

(2) City of Batavia gage during period indicated.

(3) NYS Department of Public Works gage during period indicated.

(4) This discharge was determined by the U.S.G.S. from an ice-affected stage.

(5) Includes flow to Black and Mud Creek.

(6) Gage height.

(7) Only flow data prior to Mt. Morris dam was used.

Table A1.4 - Tonawanda Creek Channel Capacities

Reach	Channel Capacity - cfs
T-1 through T-3	10,000 - 12,000
T-4 through T-7	4,000 - 6,000
T-8 through T-10	3,500 - 4,500
M-1 through M-6	200 - 400
RB-1 through RB-4	200 - 400
T-11 and T-12	3,200 - 4,200
B-1 through B-5	6,000
T-13	2,000
A-1 through A-3	3,000 - 5,000

A1.14 Peak Discharge and Discharge-Duration-Frequency Studies

Peak discharge-frequency and discharge-duration-frequency analyses were used in the design of the flood attenuation structures for this study. Streamflow data through water-year 1977 for the gaging stations listed in Table A1.3b, with the exceptions of Tonawanda Creek at Attica and Black Creek at Swormville, were used in a regional frequency study to determine the statistical parameters of mean annual discharge, Q_m; standard deviation, s; and skew coefficient, g. The analyses were made using the HEC computer program HEC-46 regional frequency computation for peak, 1-, 3-, 7-, 15-, and 30-day flow duration. The program computes the frequency statistics for recorded events at each station and duration. Missing events are synthesized to form complete sets of events for all years of record at all stations, with intercorrelations preserved. The statistics for each station are adjusted to the complete period of record. Regression analyses were then performed to determine relationships between drainage area and Q_m, s, and g. Peak discharge and discharge-duration-frequency curves were determined by a Log Pearson Type III analysis using the appropriate statistical parameters for the corresponding drainage area with an expected probability adjustment. Paragraphs A1.15 through A1.22 describe the procedures followed and results of the frequency analysis in more detail.

A1.15 A regional frequency analysis used maximum annual instantaneous peak and 1-, 3-, 7-, 15-, and 30-day discharge data from records, through water year 1977, for the gaging stations listed in Table A1.3b. Q_m, s, and g were determined for each station. On Plates A2 and A3 peak discharge curves with and without expected probability adjustment for Tonawanda Creek at Batavia and Alabama are presented.

The observed annual peaks are shown along with the 5 and 95 percent confidence limits. These discharge data reflect natural watershed effects on streamflow. During high flows, floodwaters enter the Ransom and Black Creek Watersheds upstream from the Rapids gage on Tonawanda Creek and are, therefore, not measured at the gage. Thus, the Q_m, s, and g values computed from the Rapids streamflow data were inaccurate and were not used in the final analysis. Further discussion on the interbasin diversions may be found in paragraph A1.40. A linear regression analysis was then made to relate Q_m, s, and g to drainage area for each duration.

A1.16 A plot Q_m for all durations and for each station versus drainage area suggested general groupings by two distinct geographic areas: upstream and downstream of Batavia. This is consistent with the physiography of the area. The Tonawanda Creek watershed includes portions of two physiographic provinces. The Cattaraugus Hills are separated by deeply-eroded valleys with relatively steep sides and slopes, while the Erie-Ontario lowland is slightly undulating with flat slopes. Further discussion of the physiography of the region may be found in the Main Report (Section II, Physiography). The Q_m versus DA relations were further defined by three relations: streams downstream from Batavia and tributary to Tonawanda Creek, areas along the mainstem of Tonawanda Creek downstream from Batavia, and areas upstream from Batavia. Since a perfect correlation does not exist between the mean annual discharge and drainage area, a residual was computed for each station. The residual, A_m, reflects the difference between the discharge computed by the regression equation and the observed value. These values were plotted on a map at the centroid of the drainage area in order to obtain an average value of the residual for areas upstream and downstream from Batavia, and are shown on Plate A4a for the peak duration. The regional residuals for the peak discharge from this were found to be zero. The residuals for the other durations were also found to be zero. Shown on Plates A4a and A4c are the applicable relations between peak and other duration discharges and drainage area.

A1.17 As noted on Plate A4c, Oatka Creek was not used in the peak regression analysis. The reason for this was a lack of confidence in the accuracy of the recorded maximum annual instantaneous peak discharge data and the inconsistency between the peak and other duration regressions. For example, a close examination of the rating curve for the USGS gaging station revealed that the maximum discharge, 4,010 cfs, 23 June 1972, was obtained by extending the rating curve above 1,770 cfs based on a slope-area measurement of peak flow. The 4,100 cfs should have caused considerable damage based on a Corps DM for the completed flood control project at the village of Warsaw. However, based upon field surveys during the flood, floodwaters were observed to be within banks. Consequently, the USGS rating curve was considered inaccurate for peak flows. Further, except for the peak discharge data, good regression fits were obtained for and between other durations as shown on Plate A4c. Consequently, the regression fit was done for peak duration using the remaining stations, which resulted in the expected consistency between durations.

A1.18 The standard deviation for all stations was correlated with the drainage area. Unlike the mean annual discharge, the standard deviation was fitted by one equation. A residual was calculated in a manner similar to the

mean annual discharge analysis. The standard deviation is calculated by using the regression equation with the corresponding residual. Table A1.5 lists the appropriate value for the standard deviation residual, a_s and Plate A5 presents the peak standard deviation residual map. The standard deviation regression relations appear for all durations on Plates A6 through A8.

Table A1.5 - Standard Deviation Residual, a_s

Duration	Residual, a_s D.S. of Batavia	Residual, a_s U.S. of Batavia
Peak	0.0	+0.01
1-Day	+0.02	0.0
3-Day	+0.01	+0.01
7-Day	+0.01	0.0
15-Day	0.0	0.0
30-Day	+0.01	0.0

A1.19 The unreliability of the skew coefficient at any single station with a period of record less than 100 years resulted in the determination of a regional skew coefficient. The regional skew coefficients were developed by weighting the station skew coefficient with the period of record as follows:

$$g_r = \sum_{i=1}^{N} \frac{N_i}{N_{tot}} g_i \qquad (1)$$

where

g_r = Regional skew coefficient for the given duration.
N_i = Number of years of record at station (i).
N_{tot} = Total number of years of record for all stations.
g_i = Skew coefficient for station (i).

A1.20 An adopted skew coefficient was then calculated for each station in accordance with the method presented in Bulletin 17A(1) If station records of 25 to 100 years in length are available, a weighted skew coefficient should be calculated with the station skew given a weight of (N-25)/75 and the generalized (regional) skew given a weight of 1.0-(N-25)/75. Thus:

$$g = g_s \frac{(N-25)}{75} + g_r \left(1.0 - \frac{(N-25)}{75}\right) \qquad (2)$$

(1) Guidelines for Determining Flood Flow Frequency, Bulletin 17A, United States Water Resources Council, Washington, DC, 1977.

where

g = Adopted Station Skew
g_s = Station Skew
g_r = Regional Skew

A1.21 For peak flows, the adopted skew was correlated with the drainage area for the main stem of Tonawanda Creek downstream from Batavia, and for areas upstream from Batavia. For tributaries entering Tonawanda Creek downstream from Batavia, the peak regional skew coefficient was selected. Table A1.6 lists the appropriate skew coefficients. The plotting of the skew coefficient versus drainage area for the peak duration is found on Plate A9. Plates A10-A14 present and adopted and raw station skew versus the logarithm of the drainage area for their respective durations. Since the adopted station skews lie close to the regional skew, the regional skew was used in the calculation of the discharge-duration-frequency curves. Table A1.6 lists the appropriate skew coefficient for the given duration. These skew coefficients were considered applicable to the entire Tonawanda Creek Watershed.

Table A1.6 - Skew Coefficient, g

Duration	Skew Coefficient: Main Stem - D.S. of Batavia	Skew Coefficient: U.S. of Batavia	Skew Coefficient: Tribs - D.S. of Batavia
Peak	g = .388 (log D.A.) - 1.21	g = .0986 (log D.A.) - .3427	-0.12
1-Day	-0.15		
3-Day	-0.21		
7-Day	-0.06	Applicable to Entire Watershed	
15-Day	0.11		
30-Day	0.20		

A1.22 Peak discharge-frequency curves for selected points along Tonawanda Creek are shown on Plates A15 and A16. The 1-, 3-, 7-, 15-, and 30-day frequency curves are shown on Plate A17 for Tonawanda Creek at Batavia. Also shown is the peak discharge-frequency curve. These curves were computed from Log Pearson Type III analyses using the appropriate drainage and geographic area and applying an expected probability adjustment for an equivalent period of record. The equivalent period of record for the recorded and reconstituted flows for each station, is estimated by HEC-46 by adding the determination coefficient for each year of reconstituted flow to the total years of recorded flows. An arithmetic average of the equivalent years of record for stations upstream and downstream was calculated and is used in computing the expected probability adjustment. Table A1.6a lists the equivalent period of record used for areas upstream and downstream from Batavia.

Table A1.6a - Equivalent Period of Record in Years

Duration	Peak	1 Day	3 Days	7 Days	15 Days	30 Days
Stations upstream from Batavia	56	60	61	62	63	63
Stations downstream from Batavia	34	31	32	32	32	30

A1.23 Discharge-Drainage Area Curves For Selected Durations

From the results of peak discharge and discharge-duration-frequency studies, discharge-duration-drainage area curves for selected return period floods were determined. Data from these curves, shown on Plates A18 through A29, were used in balanced hydrograph determinations.

A1.24 Balanced Hydrographs

Often hydrologic models are constructed from subarea unit hydrographs and the resulting flood hydrographs for historic events are compared to historic flood hydrograph data as a check of the model performance regarding timing, volume, and flood magnitude reproduction. As indicated in paragraph A1.5, the majority of the floods in the Tonawanda Creek Watershed have been caused by melting snow with moderate amounts of rainfall rather than rainfall alone. The unit hydrograph method was therefore not applicable. A period of record routing would have been the best approach, however discharge information above the proposed Reservoir Compound was not available. The lack of this information demonstrates the need for an improved Cooperative Stream Gaging Program from which funds would be availabe to support gages before a study is undertaken and not after. Because of the lack of discharge data, the balanced hydrograph approach was used.

A1.25 A balanced hydrograph may be defined as a theoretical flood hydrograph whose peak discharge and flood volume for specified durations have identical frequencies of occurrence. The shape of this theoretical hydrograph is patterned after the observed hydrograph of an actual flood which has occurred in the watershed. The procedure used in determining balanced hydrographs for this study follows.

A1.26 First, a pattern hydrograph was selected having an adequate duration and a shape which was typical of most floods occurring in the watershed. It is important that a pattern hydrograph compatible with the input frequency data is selected, otherwise odd-shaped balanced hydrographs may result. Since the majority of significant floods in the Tonawanda Creek Watershed have been the result of precipitation plus snowmelt during the late winter months, the 28 March through 7 April 1960 floods at Linden, Batavia, Alabama, and the reconstituted hydrograph at Rapids were selected as the pattern floods for watershed and subwatersheds investigated in this study. The

reconstitution of the 1960 flood at Rapids is discussed in paragraph A1.44. For subwatersheds upstream from Batavia, the 1960 flood at Linden was used. For Batavia, Alabama, and Rapids, the 1960 flood at those locations was used. Using the derived routing criteria, discussed in paragraphs A1.33 through A1.39, the reconstituted 1960 flood at Rapids was routed to the confluence of Mud Creek with Tonawanda Creek and used as the pattern hydrograph at the confluence. The 50-year balanced flood at the confluence with Mud Creek was routed to the confluence of Ransom Creek with Tonawanda Creek and used as the pattern hydrograph at the location. The Linden, Batavia, and Alabama pattern hydrographs used in this study are shown on Plate A30. The reconstituted 1960 flood at Rapids is shown on Plate A62.

A1.27 Balanced hydrographs were calculated for 500-, 200-, 100-, 50-, 20-, 10-, and 2-year return periods. These were computed using the proper pattern hydrograph and the peak and 1-, 3-, 7-, 15-day duration discharges from Plate A18 through A29 for the appropriate drainage area and return period. Computer program HEC-1 "Flood Hydrograph Package" was utilized in the above calculations. The 200-year balanced hydrographs for Batavia and Alabama, determined in this manner and labeled "Computed at Gage," are shown on Plates A31 and A32. Also shown for comparison are the Batavia and Alabama 200-year routed hydrographs, labeled "Routed and Combined," determined by routing and combining with 200-year local inflow.

A1.28 Unit Hydrograph and Flood Routing Criteria, General

No further consideration was given the unit hydrograph and flood routing criteria developed in the 1975 Feasibility Report. Attention was focused, however, on the development of flood routing criteria for Tonawanda Creek to the confluence with Ransom Creek. During high flows, streamflow data at the Rapids, NY, gage is inaccurate due to flood water entering the Mud and Ransom-Black Creek Watersheds upstream from the gage. Diversion discharge rating curves, shown on Plates A40 and A41, were developed for this overflow, allowing the usage of the streamflow data at the Rapids gage, and the reconstitution of the 1960 flood.

A1.29 Unit Hydrographs

Under Section 214 of the 1965 Rivers and Harbor Act, the Buffalo District performed hydrologic studies to determine unit hydrograph criteria for numerous streams in Western New York. The following is a presentation of results of prior studies and how they were used in this study.

A1.30 In prior studies, 3-hour unit hydrographs were derived from storm studies at the gaging stations listed in Table A1.3b, with the exception of Oatka Creek at Warsaw and Tonawanda Creek at Alabama and Rapids. Storms studied included the June 1944, October 1945, May 1957, April 1961, May 1961, and April 1963 storms. The Clark method of synthesis was used in determining these unit hydrographs. (No explanation of the Clark method will be given here, but a concise description of the method can be found in most textbooks on hydrology). These unit hydrographs were then adjusted by altering the Clark parameters R and Tc until it was possible to closely approximate the observed hydrographs of the recorded storms. Tc and R are time of runoff

concentration and watershed storage parameters, respectively. Next, an attempt was made to determine a relationship between these Clark parameters and typical watershed characteristics such as stream slope, drainage area, stream length, and drainage area divided by stream length.

A1.31 After considerable examination of the various watershed parameters, it was found that definite relationships existed between average stream slope and Clark's Tc and between Clark's R and drainage area. These relationships are shown on Plates A33 and A34. The reproduction of recorded storms on Tonawanda Creek at Batavia using the Tc and R values from the generalized curves showed good results. To demonstrate this, a storm reproduction is included on Plate A35 for the May 1957 storm for Tonawanda Creek at Batavia. Three-hour unit hydrographs determined using the generalized Tc and R relationships for subwatersheds upstream from Alabama and at Batavia are shown on Plate A36.

A1.32 It should be pointed out that these unit hydrographs were derived from floods that contained no snowmelt. Consequently, Standard Project Flood, SPF, and Probable Maximum Flood, PMF, determinations did not include snowmelt. The rationale for this is described in paragraph A1.60. However, Spillway Design Flood, SDF, determinations for considered structures were made including a volume of runoff from snowmelt preceeding the SDF. This is discussed in more detail in Section A2.

A1.33 Routing Criteria

The development of routing constants and local inflow in areas not previously determined was accomplished mainly through the usage of computer program HEC-1, flood hydrograph package. A complete Tonawanda Creek routing schematic is shown on Plate A37. This routing criteria was used for the balanced hydrograph, 1960 and 1977 flood routings. Routing criteria for the March 1978 flood is discussed in paragraph A1.46.

A1.34 Balanced hydrograph routings began along Tonawanda Creek at Alexander, NY, as inflow to the Upper Reservoir area. A Modified Puls routing was made through this area for existing conditions as the flood wave would experience large attenuation due to the storage upstream of the DL&WRR (Erie RR) embankment. Muskingum routing constants developed in the 1975 report for Tonawanda Creek from Alexander to the mouth of Little Tonawanda were used for this reach. The Little Tonawanda Creek at mouth hydrograph was combined with the routed Tonawanda Creek hydrograph at this confluence. The time of peak for the Little Tonawanda Creek at the mouth was made to coincide with the routed Tonawanda hydrograph. An analysis of the September 1977 and March 1978 floods support this assumption.

A1.35 Considerable field surveys were made to determine the extent of natural storage in the Lower Reservoir area. Plate A38 shows the expanse of area. Previously, Area 1 was only considered in the existing conditions storage routings. It was found that the section bounded by Ellicott Street, the Lehigh Valley Railroad (LVRR), and Town Line Road (Area 2) also is able to contain water beginning with elevation 891 feet USC&GS datum. A road

profile of Rt. 98 indicated a dip in the road near Dodgeson Road. At elevation 901 feet USC&GS datum, storage becomes available in the area bounded by Rt. 98, Dodgeson, Wortendyke, and Pike Road (Area 3). The stored water in Area 3 flows over Pike Road into Area 5. This water eventually drains into Bowen Creek via culverts under Wortendyke Road. Water escapes through the Erie Railroad opening of the LVRR once the pool elevation reaches 899 feet U.S.C.&G.S. datum, filling the area bounded by the LVRR and Conrail tracks west of Batavia (Area 4). These additional storage areas were taken into account during the flood routings.

A1.36 The computer program REVPULS, developed for this report, reverse Modified Puls routed the hydrograph at Batavia through the storage upstream of the LVRR embankment. Subtracting this reverse-routed hydrograph from the combined hydrograph at the confluence with Little Tonawanda Creek resulted in the local inflow above Batavia. The addition of the local inflow with the combined hydrograph results in the total inflow hydrograph at the Lower Reservoir site. This hydrograph was then routed by Modified Puls to obtain the hydrograph at Batavia, NY. An example is shown on Plate A31 where the 200-year balanced hydrographs for subwatersheds upstream from Batavia were routed and combined resulting in the 200-year balanced hydrograph at Batavia labeled "Routed and Combined." Also shown is the 200-year balanced hydrograph determined for Batavia directly from discharge-duration-return period-drainage area curves and the 1960 flood hydrograph at Batavia as a pattern flood.

A1.37 Muskingum routing criteria were computed for the reach between Batavia and Alabama by HEC-1 optimization using the Tonawanda Creek at Batavia and Alabama 1960 flood hydrographs. Local inflow for this reach was determined by subtracting the routed Batavia hydrograph from the Alabama hydrograph. The 200-year balanced hydrograph labeled "Routed and Combined" on Plate A32 for Alabama resulted from routing and combining subwatershed balanced hydrographs. Also shown is the 200-year balanced hydrograph at Alabama determined from discharge-duration-return period-drainage area curves and the 1960 flood hydrograph at Alabama as a pattern flood.

A1.38 An important location along Tonawanda Creek is the confluence with Ledge Creek. A stage recorder does not exist at this location. Hence, hydrographs at this location had to be synthesized. Using the 1960 flood hydrographs at Alabama and Rapids, routing constants and local inflow were derived. The travel time from Alabama to Ledge was proportioned by distance. The local inflow at the confluence was derived by proportioning the local inflow between Alabama and Rapids by drainage area with the timing appropriately adjusted. The resulting synthetic 1960 flood hydrograph at Ledge was used as the pattern hydrograph for the balanced hydrograph routings.

A1.39 Travel times downstream of the Rapids gage were derived by proportion based upon the 1964 flood. A travel time of 10 hours occurred from Rapids to the staff gage on a maintenance building on Tonawanda Creek Road (at river mile 3) for this flood. This was the only travel time information available. A Muskingum attenuation constant (x) of 0.3 was selected because of minimal overbank flooding as shown in the Flood Plain Information Report

for Tonawanda Creek (2). The FPI report is superseded by results of hydrologic analyses presented in this appendix.

A1.40 Diversion Rating Curves For Overflow to Mud and Black Creeks

During high flows, Tonawanda Creek flood water is subject to partial diversion to Mud Creek downstream of Alabama. For computation purposes, the diversion rating curve was based upon the discharge at Alabama. Using highwater marks for the 1962 and 1960 floods on Mud Creek, channel bottom, and Architect Engineer's cross sections, a backwater analysis was made. It was assumed that the peak Mud Creek discharge was the overflow discharge, with the local Mud Creek runoff peaking before Tonawanda Creek. Field observations during flooding support this assumption. The diversion rating curve was determined using information from the 1956 and 1960 flood, and profiles and discharges for the 100-year and SPF floods from the Flood Plain Information Report for Tonawanda Creek(2). Plate A40 presents the diversion rating curve for Mud Creek.

A1.41 Beeman Creek enters Tonawanda Creek approximately one mile upstream of Rapids, NY. Highwater on Tonawanda Creek will back up Beeman Creek to overflow Salt Road (Rt. 268) and enter the Black Creek Watershed. Photo 2 in the Tonawanda Creek Main Report of the 1960 flood shows this effect. A diversion discharge rating curve (Plate A41) was constructed by fitting a curve through measured discharges for the 1956, 1957, and 1960 floods. It was estimated that diversion begins when the flow measured at the Rapids gage is 4,000 cfs. Previous field observations of flooding support this assumption.

A1.42 HEC-5C Modeling of the Tonawanda Creek Watershed

With the routing criteria and local inflow derived using HEC-1, the computer program HEC-5C "Simulation of Flood Control and Conservation Systems" was used to model the Tonawanda Creek Watershed from Alexander, NY, downstream to the confluence with Ransom Creek. Using the diversion discharge rating curves, the program was able to make the necessary diversions and route and combine the overflow hydrographs. Plate A37 shows the complete routing schematic used for the balanced hydrograph routings.

A1.43 Tables A1.7 through A1.13 list the results of the balanced hydrograph routings. The tables give the drainage area of the subwatershed along with the volume and peak discharge of the flood. The total volume in inches reported at each location is the runoff which occurred for the particular flood over a time of 18.75 days. Plates A42 through A58 show the 200-, 50-, 2-year flood hydrographs at selected stream locations. Discussion of the routings with the reservoirs may be found in Section A2.

(2) Flood Plain Information: Tonawanda Creek and Its Affected Tributaries, Erie and Niagara Counties, Corps of Engineers, Buffalo District, 1971.

Table A1.7 - 500-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing Inches	Existing Peak-cfs	Up. Res. Only Inches	Up. Res. Only Peak-cfs	Res. Compound Inches	Res. Compound Peak-cfs
Tonawanda at Alexander	102	10.6	15,000	10.6	15,000	10.6	15,000
Outflow: Upper Reservoir	102	10.6	12,200	10.6(1)	12,200	10.6(1)	12,200
Little Tonawanda at Mouth	38	10.6	6,200	10.6	6,200	10.6	6,200
Local Inflow: Alexander to Batavia	31	7.5	2,600	7.5	2,600	7.5	2,600
Inflow to Lower Reservoir	171	10.0	17,200	10.0	17,200	10.0	17,200
Outflow: Lower Reservoir	171	10.0	9,850	9.9	8,400	9.9(1)	6,500
Local Inflow: Batavia to Alabama	60	6.4	3,030	6.4	3,030	6.4	3,030
Tonawanda at Alabama	231	8.9	12,000	8.9	10,700	8.8	8,740
Diversion to Mud Creek	231	.7	2,500	.63	2,290	.7	1,920
Tonawanda at Alabama less diversion to Mud Creek	231	8.2	9,520	8.3	8,410	8.1	6,820
Ledge Creek and Tonawanda Local	87	7.4	4,110	7.4	4,110	7.4	4,110
Tonawanda Creek downstream confluence with Ledge	318	7.9	12,600	8.0	11,500	7.9	10,300
Local Inflow: Ledge to Rapids	40	7.8	3,520	7.8	3,520	7.8	3,520
Diversion to Black Creek	358	1.4	6,800	1.4	6.050	1.3	5,150
Tonawanda at Rapids less diversions	358	6.5	6,970	6.6	6,830	6.5	6,600
Mud Creek and Tonawanda Local	56	8.3	2,440	8.3	2,440	8.3	2,440
Tonawanda below confluence with Mud Creek	414	7.1	11,730	7.2	11,300	7.2	10,500
Ransom-Black and Tonawanda Local	86	8.2	3,160	8.2	3,160	8.2	3,160
Tonawanda below confluence with Ransom	500	8.2	20,800	8.2	19,500	8.2	17,900

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 1.2 inches
Lower Res. - 1.7 inches

Table A1.8 - 200-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing Inches	Existing Peak-cfs	Up. Res. Only Inches	Up. Res. Only Peak-cfs	Res. Compound Inches	Res. Compound Peak-cfs
Tonawanda at Alexander	102	9.5	14,000	9.5	14,000	9.5	14,000
Outflow: Upper Reservoir	102	9.5	11,400	9.5(1)	11,400	9.5(1)	11,400
Little Tonawanda at Mouth	38	9.5	5,650	9.5	5,650	9.5	5,650
Local Inflow: Alexander to Batavia	31	7.0	2,440	7.0	2,440	7.0	2,440
Inflow to Lower Reservoir	171	9.0	16,000	9.0	16,000	9.0	16,000
Outflow: Lower Reservoir	171	9.0	9,100	8.9	7,540	8.9(1)	5,780
Local Inflow: Batavia to Alabama	60	5.0	2,560	5.0	2,560	5.0	2,560
Tonawanda at Alabama	231	7.8	11,300	7.9	9,850	7.8	8,160
Diversion to Mud Creek	231	0.6	2,390	0.5	2,130	0.5	1,810
Tonawanda at Alabama less diversion to Mud Creek	231	7.2	8,940	7.4	7,720	7.3	6,350
Ledge Creek and Tonawanda Local	87	7.4	3,280	7.4	3,280	7.4	3,280
Tonawanda Creek downstream confluence with Ledge	318	7.2	11,670	7.4	10,500	7.3	9,140
Local Inflow: Ledge to Rapids	40	6.7	2,360	6.7	2,360	6.7	2,360
Diversion to Black Creek	358	1.1	5,910	1.1	5,000	1.0	4,050
Tonawanda at Rapids less diversions	358	6.0	6,800	6.2	6,550	6.1	6,260
Mud Creek and Tonawanda Local	56	6.5	1,930	6.5	1,930	6.5	1,930
Tonawanda below confluence with Mud Creek	414	6.4	10,800	6.4	10,200	6.4	9,700
Ransom-Black and Tonawanda Local	86	7.7	3,060	7.7	3,060	7.7	3,060
Tonawanda below confluence with Ransom	500	7.4	18,500	7.4	17,400	7.4	16,200

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 1.2 inches
Lower Res. - 1.5 inches

Table A1.9 - 100-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing		Up. Res. Only		Res. Compound	
		Inches	Peak-cfs	Inches	Peak-cfs	Inches	Peak-cfs
Tonawanda at Alexander	102	8.8	12,500	8.8	12,500	8.8	12,500
Outflow: Upper Reservoir	102	8.8	10,400	8.8(1)	10,400	8.8(1)	10,400
Little Tonawanda at Mouth	38	9.0	5,100	9.0	5,100	9.0	5,100
Local Inflow: Alexander to Batavia	31	6.0	2,500	6.0	2,500	6.0	2,500
Inflow to Lower Reservoir	171	8.3	14,700	8.3	14,000	8.3	14,000
Outflow: Lower Reservoir	171	8.3	8,470	8.3	6,770	8.3(1)	5,450
Local Inflow: Batavia to Alabama	60	4.8	2,340	4.8	2,340	4.8	2,340
Tonawanda at Alabama	231	7.3	10,500	7.3	8,850	7.3	7,650
Diversion to Mud Creek	231	0.5	2,250	0.4	1,940	0.4	1,680
Tonawanda at Alabama less diversion to Mud Creek	231	6.8	8,240	6.9	6,910	6.9	5,970
Ledge Creek and Tonawanda Local	87	6.1	3,070	6.1	3,070	6.1	3,070
Tonawanda Creek downstream confluence with Ledge	318	6.6	10,800	6.7	9,470	6.6	8,570
Local Inflow: Ledge to Rapids	40	6.5	1,900	6.5	1,900	6.5	1,900
Diversion to Black Creek	3[illegible]	0.9	5,140	0.8	4,190	0.8	3,550
Tonawanda at Rapids less diversions	358	5.7	6,600	5.8	6,300	5.8	6,120
Mud Creek and Tonawanda Local	56	7.0	1,580	7.0	1,580	7.0	1,580
Tonawanda below confluence with Mud Creek	414	6.1	10,200	6.2	9,560	6.2	9,100
Ransom-Black and Tonawanda Local	86	7.2	2,430	7.2	2,430	7.2	2,430
Tonawanda below confluence with Ransom	500	6.9	17,200	6.9	15,800	6.9	14,700

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 1.2 inches
Lower Res. - 1.3 inches

Table A1.10 - 50-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing		Up. Res. Only		Res. Compound	
		Inches	Peak-cfs	Inches	Peak-cfs	Inches	Peak-cfs
Tonawanda at Alexander	102	8.0	11,200	8.0	11,200	8.0	11,200
Outflow: Upper Reservoir	102	8.0	9,440	8.0(1)	9,350	8.0(1)	9,350
Little Tonawanda at Mouth	38	8.0	4,650	8.0	4,650	8.0	4,650
Local Inflow: Alexander to Batavia	31	8.0	2,080	8.0	2,080	8.0	2,080
Inflow to Lower Reservoir	171	8.0	13,700	7.9	10,000	7.9	10,000
Outflow: Lower Reservoir	171	8.0	7,730	7.9	5,930	7.8(1)	5,240
Local Inflow: Batavia to Alabama	60	3.3	2,090	3.3	2,090	3.3	2,090
Tonawanda at Alabama	231	6.7	9,540	6.6	7,800	6.6	7,180
Diversion to Mud Creek	231	0.5	2,070	0.3	1,720	0.3	1,540
Tonawanda at Alabama less diversion to Mud Creek	231	6.2	7,470	6.3	6,080	6.3	5,640
Ledge Creek and Tonawanda Local	87	5.9	2,830	5.9	2,830	5.9	2,830
Tonawanda Creek downstream confluence with Ledge	318	6.1	9,920	6.2	8,570	6.2	8,150
Local Inflow: Ledge to Rapids	40	5.1	1,640	5.1	1,640	5.1	1,640
Diversion to Black Creek	358	0.6	4,660	0.5	3,660	0.5	3,370
Tonawanda at Rapids less diversions	358	5.3	6,420	5.5	6,150	5.5	6,060
Mud Creek and Tonawanda Local	56	5.8	1,620	5.8	1,620	5.8	1,620
Tonawanda below confluence with Mud Creek	414	5.6	9,610	5.7	8,960	5.7	8,710
Ransom-Black and Tonawanda Local	86	6.7	2,270	6.7	2,270	6.7	2,270
Tonawanda below confluence with Ransom	500	6.2	15,800	6.2	14,100	6.2	13,600

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 1.2 inches
Lower Res. - 1.1 inches

Table A1.11 - 20-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing Inches	Existing Peak-cfs	Up. Res. Only Inches	Up. Res. Only Peak-cfs	Res. Compound Inches	Res. Compound Peak-cfs
Tonawanda at Alexander	102	7.0	9,600	7.0	9,600	7.0	9,600
Outflow: Upper Reservoir	102	7.0	8,450	6.9(1)	4,740	6.9(1)	4,740
Little Tonawanda at Mouth	38	7.0	3,950	7.0	3,950	7.0	3,950
Local Inflow: Alexander to Batavia	31	5.8	1,820	5.8	1,820	5.8	1,820
Inflow to Lower Reservoir	171	6.7	11,700	6.7	6,930	6.7	6,930
Outflow: Lower Reservoir	171	6.7	6,650	6.7	4,930	6.7(1)	4,620
Local Inflow: Batavia to Alabama	60	3.3	1,830	3.3	1,830	3.3	1,830
Tonawanda at Alabama	231	5.8	8,260	5.8	6,500	5.8	6,240
Diversion to Mud Creek	231	0.4	1,830	0.2	1,330	0.2	1,240
Tonawanda at Alabama less diversion to Mud Creek	231	5.4	6,430	5.6	5,170	5.6	5,000
Ledge Creek and Tonawanda Local	87	5.7	2,400	5.7	2,400	5.7	2,400
Tonawanda Creek downstream confluence with Ledge	318	5.5	8,600	5.0	7,390	5.6	7,220
Local Inflow: Ledge to Rapids	40	3.1	1,440	3.1	1,440	3.1	1,440
Diversion to Black Creek	358	0.4	3,360	0.4	2,510	0.3	2,400
Tonawanda at Rapids less diversions	358	4.7	6,050	4.9	5,770	4.9	5,730
Mud Creek and Tonawanda Local	56	4.9	1,450	4.9	1,446	4.9	1,446
Tonawanda below confluence with Mud Creek	414	4.9	9,050	5.0	8,200	5.0	8,060
Ransom-Black and Tonawanda Local	86	6.3	1,970	6.3	1,970	6.3	1,970
Tonawanda below confluence with Ransom	500	5.5	13,800	5.5	12,100	5.4	11,900

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 1.2 inches
Lower Res. - .8 inch

Table A1.12 - 10-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing Inches	Existing Peak-cfs	Up. Res. Only Inches	Up. Res. Only Peak-cfs	Res. Compound Inches	Res. Compound Peak-cfs
Tonawanda at Alexander	102	6.2	8,300	6.2	8,300	6.2	8,300
Outflow: Upper Reservoir	102	6.2	7,400	6.2(1)	3,550	6.2(1)	3,550
Little Tonawanda at Mouth	38	6.2	3,400	6.2	3,400	6.2	3,400
Local Inflow: Alexander to Batavia	31	5.1	1,640	5.1	1,640	5.1	1,640
Inflow to Lower Reservoir	171	6.0	10,300	6.1	6,000	5.0	6,000
Outflow: Lower Reservoir	171	6.0	5,870	6.0	4,320	6.0(1)	4,260
Local Inflow: Batavia to Alabama	60	2.5	1,640	2.5	1,640	2.5	1,640
Tonawanda at Alabama	231	5.1	7,330	5.1	5,740	5.0	5,650
Diversion to Mud Creek	231	0.3	1,580	0.1	1,080	.1	1,050
Tonawanda at Alabama less diversion to Mud Creek	231	4.8	5,750	5.0	4,760	4.9	4,600
Ledge Creek and Tonawanda Local	87	4.4	2,380	4.4	2,380	4.4	2,380
Tonawanda Creek downstream confluence with Ledge	318	4.6	7,900	4.8	6,910	4.8	6,850
Local Inflow: Ledge to Rapids	40	4.8	1,170	4.8	1,170	4.8	1,170
Diversion to Black Creek	358	0.3	2,260	0.3	2,040	0.3	2,000
Tonawanda at Rapids less diversions	358	4.3	5,820	4.5	5,560	4.5	5,540
Mud Creek and Tonawanda Local	56	4.7	1,430	4.7	1,430	4.7	1,430
Tonawanda below confluence with Mud Creek	414	4.4	8,480	4.5	7,550	4.5	7,430
Ransom-Black and Tonawanda Local	86	5.0	1,880	5.0	1,880	5.0	1,880
Tonawanda below confluence with Ransom	500	4.8	12,330	4.8	10,800	4.8	10,670

(1) Quantity of Water Stored in Reservoirs: Upper Res. = 1.2 inches
Lower Res. = .7 inch

Table A1.13 - 2-Year Balanced Hydrograph Routings

Location	D.A. Miles^2	Existing		Up. Res. Only		Res. Compound	
		Inches	Peak-cfs	Inches	Peak-cfs	Inches	Peak-cfs
Tonawanda at Alexander	102	4.2	5,000	4.2	5,000	4.2	5,000
Outflow: Upper Reservoir	102	4.2	4,570	4.2(1)	1,500	4.2(1)	1,500
Little Tonawanda at Mouth	38	4.2	2,010	4.2	2,010	4.2	2,010
Local Inflow: Alexander to Batavia	31	2.9	1,060	2.9	1,060	2.9	1,060
Inflow to Lower Reservoir	171	4.0	6,340	4.0	3,410	4.0	3,410
Outflow: Lower Reservoir	171	4.0	3,870	4.0	2,530	4.0(1)	2,000
Local Inflow: Batavia to Alabama	60	1.9	1,090	1.9	1,090	1.9	1,090
Tonawanda at Alabama	231	3.3	4,840	3.4	3,530	3.4	2,480
Diversion to Mud Creek	231	0^+	560	0	0	0	0
Tonawanda at Alabama less diversion to Mud Creek	231	3.3	4,280	3.4	3,530	3.4	2,480
Ledge Creek and Tonawanda Local	87	2.8	1,610	2.8	1,610	2.8	1,610
Tonawanda Creek downstream confluence with Ledge	318	3.2	5,780	3.2	4,860	3.2	3,430
Local Inflow: Ledge to Rapids	40	3.5	935	3.5	935	3.5	935
Diversion to Black Creek	358	0.1	1,270	0^+	640	0	0
Tonawanda at Rapids less diversions	358	3.1	5,140	3.2	4,710	3.2	3,950
Mud Creek and Tonawanda Local	56	2.8	685	2.8	685	2.8	685
Tonawanda below confluence with Mud Creek	414	3.0	5,560	3.1	4,930	3.1	4,100
Ransom-Black and Tonawanda Local	86	3.4	1,750	3.4	1,750	3.4	1,750
Tonawanda below confluence with Ransom	500	3.2	8,300	3.2	6,480	3.2	5,730

(1) Quantity of Water Stored in Reservoirs: Upper Reservoir - 1.0 inches
Lower Reservoir - 1.2 inches

Table A1.14 - March-April, 1960 Flood

Location	D.A. Miles²	Existing: Inches	Existing: Peak-cfs	Up. Res. Only: Inches	Up. Res. Only: Peak-cfs	Res. Compound: Inches	Res. Compound: Peak-cfs
Tonawanda at Alexander	102	No Data Available		Inflow to Upper Reservoir not available and hence, no routings were made.		Routings begin with inflow to Lower Reservoir and hence, do not show effect of Upper Reservoir.	
Outflow: Upper Reservoir	102	No Data Available					
Little Tonawanda at Mouth	38	No Data Available					
Local Inflow: Alexander to Batavia	31	No Data Available					
Inflow to Lower Reservoir	171	5.5	11,020			5.5	11,020
Outflow: Lower Reservoir	171	5.5	7,200			5.5(1)	5,610
Local Inflow: Batavia to Alabama	60	4.7	2,420			4.7	2,420
Tonawanda at Alabama	231	5.2	7,980			5.2	6,490
Diversion to Mud Creek	231	.4	1,780			.4	1,320
Tonawanda at Alabama less diversion to Mud Creek	231	4.8	6,200			4.8	5,170
Ledge Creek and Tonawanda Local	87	7.5	3,520			7.5	3,520
Tonawanda Creek downstream confluence with Ledge	318	5.6	9,320			5.6	8,410
Local Inflow: Ledge to Rapids	40	6.2	1,490			6.2	1,490
Diversion to Black Creek	358	.9	4,280			.8	3,580
Tonawanda at Rapids less diversions	358	4.8	6,280			4.8	6,110
Mud Creek and Tonawanda Local	56						
Tonawanda below confluence with Mud Creek	414						
Ransom-Black and Tonawanda Local	86						
Tonawanda below confluence with Ransom	500						

(1) Quantity of Water Stored in Lower Reservoir = 1.4 inches

Table A1.15 - September, 1977 Flood

Location	D.A. Miles^2	Existing		Up. Res. Only		Res. Compound	
		Inches	Peak-cfs	Inches	Peak-cfs	Inches	Peak-cfs
Tonawanda at Alexander	102	5.5	8,640	5.5	8,640	5.5	8,640
Outflow: Upper Reservoir	102	5.5	7,320	5.5(1)	2,000	5.5(1)	2,000
Little Tonawanda at Mouth	38	5.3	2,390	5.3	2,390	5.3	2,390
Local Inflow: Alexander to Batavia	31	5.0	2,500	5.0	2,500	5.0	2,500
Inflow to Lower Reservoir	171	5.5	10,800	5.3	6,860	5.3	6,860
Outflow: Lower Reservoir	171	5.5	5,110	5.3	3,720	5.5(1)	2,000
Local Inflow: Batavia to Alabama	60	2.5	1,510	2.5	1,510	2.5	1,510
Tonawanda at Alabama	231	4.6	5,010	4.5	3,940	4.5	3,060
Diversion to Mud Creek	231	.6	700	0	0	0	0
Tonawanda at Alabama less diversion to Mud Creek	231	4.0	4,310	4.5	3,940	4.5	3,060
Ledge Creek and Tonawanda Local	87	-	-	-	-	-	-
Tonawanda Creek downstream confluence with Ledge	318						
Local Inflow: Ledge to Rapids	40						
Diversion to Black Creek	358						
Tonawanda at Rapids less diversions	358						
			NO DATA AVAILABLE				
Mud Creek and Tonawanda Local	56						
Tonawanda below confluence with Mud Creek	414						
Ransom-Black and Tonawanda Local	86						
Tonawanda below confluence with Ransom	500						

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 1.1 inches
Lower Res. - 1.6 inches

Table A1.16 - March, 1978 Flood

Location	D.A. Miles^2	Existing Inches	Existing Peak-cfs	Up. Res. Only Inches	Up. Res. Only Peak-cfs	Res. Compound Inches	Res. Compound Peak-cfs
Tonawanda at Attica	82	2.6	2,110	2.6	2,110	2.6	2,110
Local Inflow: Attica at Alexander	20	6.5	650	6.5	650	6.5	650
Tonawanda at Alexander	102	3.4	3,740	3.4	3,740	3.4	3,740
Outflow: Upper Reservoir	102	3.4	2,820	3.4(1)	1,500	3.4(1)	1,500
Local Inflow: Alexander to confluence	31	4.3	1,820	4.3	1,820	4.3	1,820
Little Tonawanda at Linden	22.7	3.6	630	3.6	630	3.6	630
Local: Linden to confluence	15.3	3.7	750	3.7	750	3.7	750
Inflow: Lower Reservoir	171	3.6	5,630	3.7	4,070	3.7	4,070
Outflow: Lower Reservior	171	3.6	3,740	3.7	2,930	2.8(1)	2,000
Local Inflow: Batavia to Alabama	60	9.0	2,650	9.0	2,650	9.0	2,650
Tonawanda at Alabama	231	5.0	4,340	5.0	3,700	4.4	3,200
Diversion to Mud Creek	231	0^+	230	0	0	0	0
Tonawanda at Alabama less diversion to Mud Creek	231	5.0	4,110	5.0	3,700	4.4	3,200
Local Inflow: Alabama to Ledge	87	3.9	1,820	3.9	1,820	3 9	1,820
Tonawanda at confluence with Ledge Creek	318	4.8	6,050	4.7	5,570	4.2	4,840
Local Inflow: Ledge to Rapids	40	5.5	1,620	5.5	1,620	5.5	1,620
Diversion to Black Creek	358	.4	1,500	.2	840	.1	470
Tonawnada at Rapids less diversions	358	4.4	5,220	4.6	4,870	4.3	4,560

(1) Quantity of Water Stored in Reservoirs: Upper Res. - 0.8 inch
Lower Res. - 1.0 inches

A1.44 Table A1.14 presents the results of routing the March 1960 flood using HEC-5C. Routing begins as inflow to the Lower Reservoir area (upstream of the LVRR) and terminates at the Rapids gage. Plates A1a through A1c present the flooded areas and Plates A59 through A62 exhibit the hydrographs for the flood. Of particular note is Plate A62, reconstituted March 1960 flood at Rapids, NY. Utilizing the diversion discharge information, the total flow at the gage was derived. The reconstructed hydrograph was used as the pattern hydrograph for the balanced hydrograph routings.

A1.45 Unlike the other floods discussed in this report, the September 1977 flood was a rainfall flood. As the summertime flood of record, 7.7 inches of rain fell at Batavia for the period September 16-28 1977 (Table A1.2). Using the Clark unit hydrograph parameters, Tc and R (see Section A1.28-A1.31 and Plates A33-A34 for Clark's parameters description), an attempt was made to recreate the flood. Despite having broken the storm into two events, the storm proved too complex for such a simplistic approach. It would be necessary to separate the storm into more segments to form a more accurate reconstitution. The hydrographs upstream of Batavia were derived by reverse-routing and prorating by drainage area. Table A1.15 gives the routing results and Plates A63-A66 show the hydrographs in the Upper and Lower Reservoir area.

A1.46 Although the March 1978 flood was not a particularly noteworthy event (2-5 year), streamflow records were the most complete. Routings began along Tonawanda Creek at Attica, NY, and terminated at Rapids, NY. The routing criteria used is presented in Table A1.17.

Table A1.17 - Routing Criteria for the March 1978 Flood

Location	Routed to	Method	Number of Subreaches	K(Hrs)	X
Attica	Alexander	Muskingum	1	3	.3
Alexander	Below DLWRR	Mod Puls	-	-	-
Below DLWRR	Conf w/L. Ton.	Muskingum	2	3	.1
L. Ton. at Linden	Conf w/L. Ton.	Muskingum	1	3	.2
Conf. w/L. Ton.	Batavia	Mod Puls	-	-	-
Batavia	Alabama	Muskingum	5	3	.21
Alabama	Ledge	Muskingum	3	3	.2
Ledge	Rapids	Muskingum	3	3	.2

Routing criteria from Attica to Alexander and Linden to the confluence was developed in 1967 when the Sierks and Linden Reservoirs were under consideration. The remaining routing criteria were developed by HEC-1 optimization. Table A1.16 gives the routing results for this flood and Plates A67 through A71 present some of the routed hydrographs.

A1.47 Standard Project Flood, SPF, General

The Standard Project Flood was calculated along Tonawanda Creek between Alexander and Rapids, NY, at the same locations as was done for the balanced hydrograph routings. The Standard Project index precipitation was taken as one-half the Probable Maximum Storm index developed using Hydrometeorological Report No. 51(3). The development of the Probable Maximum Storm index is discussed later in Section A1.59-A1.60. The SPF hydrographs were calculated using the Generalized Computer Program 723-010 HEC-1 and the generalized T_c and R curves discussed in Section A1.28. The individual SPF hydrographs were routed and combined using the Generalized Computer Program 723-500 HEC-5C.

A1.48 A comparison of SPF rainfall and discharge data with other notable storms above Batavia is shown in Table A1.18. The SPF at selected locations along Tonawanda Creek is listed in Table A1.19 and A1.20. The reduction in peak discharge for the SPF between Alexander and Batavia and between Ledge and Rapids is due to natural valley storage.

A1.49 Standard Project Flood, SPF, Alexander to Rapids

As shown in Table A1.19, the results of the SPF determinations for this study differ from those presented in prior reports. A crude estimate of valley storage between Alexander and Batavia in the 1961 Interim Report(4) resulted in the low value for the SPF at Batavia. The unpublished 1976 Tonawanda Creek Report(5) utilized a refined area-capacity curve developed from topographic maps. Extensive field surveys above Batavia during 1977 further refined the area-capacity curves between Alexander and Batavia. Utilizing the refined curves and routing criteria with Hydrometeorological Report No. 51 resulted in the present SPF discharges.

A1.50 The Standard Project Index precipitation for the individual drainage areas were calculated using the isohyetal method to determine mean basin rainfall. The storm isohyetal pattern in EM-1110-2-1411(6) was used and is shown in Plate A71a. The center of the Standard Project Storm was centered over the Tonawanda Creek Watershed above Alexander, which resulted in the maximum SPF peak discharge at Batavia. The mean basin SPF rainfall and discharge for the local areas may be found in Table A1.21.

(3) Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, Hydrometeorological Report No. 51 (Washington, DC: U. S. Department of Commerce, U. S. Army Corps of Engineers, June 1978)

(4) Interim Review of Report for Flood Control, Tonawanda Creek, Batavia, NY (Buffalo, NY, U. S. Army Corps of Engineers, 1961)

(5) Buffalo Metropolitan Area, New York, Interim Report on Feasibility of Flood Plain Management in Tonawanda Creek Watershed, Appendix A (Buffalo, NY, U. S. Army Corps of Engineers, 1976)

(6) Standard Project Flood Determinations, EM 1110-2-1411, Plate 12 (Washington, DC, U. S. Army Corps of Engineers, March 1965)

Table A1.18 - Comparative Rainfall and Discharge Data, Tonawanda Creek Watershed Above Batavia

Storm Period	Duration hours	Snow on ground, inches	Total rainfall, inches	Excess rainfall or runoff inches	Peak discharge Batavia gage, cfs.	Ground Conditions
Standard Project	96	-	12.64	11.0	28,500	Saturated
7 Mar 1956	28	1-2	2.5	1.9	6,480	Partly frozen
23 Jan 1957	36	12-18	1.8	2.1	6,090	Partly frozen
31 Mar 1960	72	23	0.2	3.3	7,200	Partly frozen
25 Sep 1977	288	-	7.7	5.5	5,120	Dry

Table A1.19 - Standard Project Flood Discharges, Existing Conditions

Location	Drainage Area sq. miles	Standard Project Flood, Q in cfs: Prior Studies	1975 Study	Current Study
Little Tonawanda Creek at mouth	38.0	-	16,400	18,800
Tonawanda Creek at Alexander	102.0	-	34,600	38,500
Tonawanda Creek at Batavia	171.0	14,100	24,000	28,500
Local Area Batavia to Alabama	60.0	18,900	18,900	18,900
Tonawanda Creek at Alabama	231.0	35,200	28,400	38,500
Tonawanda Creek at Confluence with Murder-Ledge	318.0	-	-	38,800
Tonawanda Creek at Rapids	358.0	-	-	37,600

Table A1.20 - Standard Project and Probable Maximum Floods

	Probable Maximum Flood		Standard Project Flood			
	Existing*	Improved	Existing*	Improved Gates Open	Full Pool Gates Closed	Upper Reservoir (Only)
Alexander (Upper Res.)						
Inflow	81,200 cfs	81,200 cfs	38,800 cfs	38,800 cfs	38,800 cfs	38,800 cfs
Outflow	79,800 cfs	80,700 cfs	38,500 cfs	38,600 cfs	38,600 cfs	39,000 cfs
Elev.	928.4 ft.	926.5 ft.	923.8 ft.	924.5 ft.	924.5 ft.	924.5 ft.
Batavia (Lower Res.)						
Inflow	100,300 cfs	102,900 cfs	49,200 cfs	50,200 cfs	51,000 cfs	53,000 cfs
Outflow	71,000 cfs	71,000 cfs	28,500 cfs	28,400 cfs	34,600 cfs	27,500 cfs
Elev.	907.3 ft.	907.3 ft.	902.0 ft.	902.5 ft.	903.4 ft.	901.7 ft.
Alabama	NA	NA	38,500 cfs	38,400 cfs	NA	NA
Rapids	NA	NA	37,600 cfs	36,700 cfs	NA	NA

*Note - Existing condition runs have diversion of flows (less than 1,000 cfs) over Route 98 near Dodgeson Road and, therefore around Batavia from Lower Reservoir as described in paragraph A1.28.

Table A1.21 - Standard Project Local Area Rainfall and Discharges

Local Area	Drainage Area Square Miles	Mean Rainfall Inches	Peak Discharge cfs
Tonawanda at Alexander	102	11.0	38,800
Little Tonawanda Creek and Tonawanda Local: Alexander-Batavia	69	11.0	18,800
Tonawanda Local: Batavia-Alabama	60		18,900(7)
Ledge-Murder Creek	87	10.4	25,400
Tonawanda Local: Ledge Creek conflu- ence - Rapids	40	7.8	1,500

Local Area SPF hydrographs are shown on Plates A72-77.

A1.51 Routing and combining of the SPF was accomplished using HEC-5C with a 3-hour time interval which proved to be insufficient near the peak of the hydrograph. To improve the accuracy of the peak discharge a 1-hour time interval was used near the peak. This resulted in peak discharges which were consistent and credible. The routing criteria was essentially that used for the balanced hydrograph routings with a few minor changes. The outflow SPF hydrograph from the abandoned DL&WRR (Tonawanda at Alexander) was translated with no attenuation to the confluence of Little Tonawanda and Tonawanda Creeks. At this point, the local SPF hydrograph from Little Tonawanda was added. A saddle in Route 98 between Alexander and Batavia allows water to be diverted into the Bowen Creek Watershed for floods well in excess of a 500-year return period. For the SPF, the diversion is less than 1,000 cfs for the peak discharge. This diversion outflow rejoins the SPF hydrograph at the confluence of Bowen and Tonawanda Creeks. The SPF hydrograph at the Batavia less the diversion was routed using the Muskingum Method (1-step, K=3 hours, X=.21) to the confluence with Bowen Creek where it was combined with the diversion. The SPF hydrograph at Bowen Creek was then routed to Alabama by a 4-step Muskingum routing with K=3 hours and X=.21. The routing from Alabama to Rapids uses the same criteria as the balanced hydrograph routings with the exception that diversions to Mud and Black Creeks are omitted. Diversions were not taken into account because the large discharge associated with the SPF would submerge Tonawanda Creek and its tributaries.

(7) This local area SPF discharge was used in developing an SPF at Alabama for the Flood Plain Information Report, Tonawanda Creek and Tributaries, Erie and Niagara Counties, NY (Buffalo, NY, U. S. Army Corps of Engineers, August 1967, reprinted 1971)

A1.52 The Standard Project Flood was not determined downstream from Rapids as the peak discharge would experience little change. The local SPF hydrographs from the areas downstream of Rapids would contribute little to the flow traveling downstream from Rapids.

A1.53 Standard Project Flood, SPF, Stages

Standard Project Flood stages were calculated for each index point along Tonawanda Creek in the same mannor as the elevations were determined for the stage-frequency curves (see Section A3 and A4.) The SPF elevations can be found on Table A1.22. Considerable judgement was exercised in making these determinations due to the lack of available cross sectional data and back-water studies. SPF damages by reach may be found on Table A1.23. In the northeastern United States, SPF determinations are not based on a rigorous statistical analysis of streamflow or rainfall records and, hence, no return period was assigned. Peak SPF discharges and elevations may be found on all applicable rating and stage-frequency curves in this appendix. These SPF elevations along with city sewer maps and USGS quadrangle maps were used in the construction of the approximate SPF flooded area map for the city of Batavia shown on Plate A1d. The SPF discharges in Batavia for with and without project conditions are approximately the same, hence only one flooded outline is shown.

A1.54 Spillway Design Flood, SDF

Spillway Design Flood (SDF) determinations were made using criteria established in the following references:

a. EC 1110-2-27, "Policies and Procedures Pertaining to Determination of Spillway Capacities and Freeboard Allowances for Dams," dated 1 August 1966.

b. EC 1110-2-163, "Spillway and Freeboard Requirements for Dams," dated 25 August 1975.

c. Snyder, Franklin F., "Hydrology of Spillway Design: Large Structures - Adequate data," Journal of the Hydraulics Division, ASCE, Vol. 90, No. 1443, Proc. Paper 3915, May 1964.

A1.55 A high degree of conservatism is adhered to in all phases of design, construction and operation of dam and reservoir projects to assure adequate security to downstream areas against possible effects of partial breaching or failure of any structure. Functional design standards necessary to meet this requirement during floods will conform with one of four standards described in the referenced EC's. After consideration of these standards, structures in this study were designed following the policies and procedures set forth for Standard 3.

A1.56 Standard 3 calls for, "the dam and reservoir storage regulation facilities to be designed so that any breaching of the structure from overtopping by infrequent floods would occur at gradual rates, such that associated increases in flood heights and adverse effects downstream would be within acceptable limits." Standard 3 must be utilized with unusual caution

and discretion, based on judgement of all pertinent factors, including local conditions and probable future developments. Normally, Standard 3 is applied in new designs, primarily to projects in which maximum storage impoundments to top of nonoverflow portions of the dam would not exceed a few thousand acre-feet; where differences between water levels above and below the dams would be only a few feet when the peak spillway design flood level occurred and where general conditions, with respect to site features and safety requirements, are acceptable. Where Standard 3 is justified by circumstances, the following criteria normally should be observed in the design of projects impounding less than a few thousand acre-feet: (a) normal use regulating outlets and service spillways shall be capable of safely passing floods equal to a 100-year frequency event without flow over the emergency spillway; (b) the top elevation and design of main nonoverflow sections of the dam shall be adequate to avoid overtopping or breaching during a flood at least equal to the Standard Project Flood.

A1.57 The flood attentuation structures considered at Alexander and Batavia, NY, would be low-level structures with differences between water levels above and below the structures of only a few feet. Storage to top of nonoverflow portions of the structure would be only a few thousand acre-feet and emergency spillways and flowage easements would be provided to assure adequate security to downstream areas against possible breaching or failure.

A1.58 After due consideration of standards, policies, and procedures, the Standard Project Flood was selected as the Spillway Design Flood for considered structures in this study. SDF determinations for considered structures are presented in Section A2.

A1.59 <u>Probable Maximum Flood, PMF</u>

The Probable Maximum Flood, PMF, was developed using the guidelines established in Hydrometeorological Report No. 51(8). Rainfall depth-basin area curves for PMF storms of 6-, 12-, 24-, 48-, and 72-hour durations can be found on Plate A77a. The time distribution of the rainfall patterns, similar to those in HM 43(9) are shown on Plate A77b. The selected PMF hydrograph was calculated using Pattern No. 1.

A1.60 Snowmelt in conjunction with rainfall was not considered for Probable Maximum Storm calculations. In a letter dated 15 November 1976, from the National Oceanic and Atmospheric Administration, the average snow water content for the Tonawanda Watershed was estimated to be 10 inches for 15 March, and five inches for 15 April. The Probable Maximum Precipitation estimates to fall upon the above snowpack ranged from 53 percent to 66 percent of the all-season Probable Maximum Precipitation for the period 15 March to 15 April. With the all-season Probable Maximum Precipitation equal to 21.5 inches of rainfall the total water content available on 15 March is 21.4 inches, and for 15 April 19.2 inches, both less than the all-season Probable Maximum Precipitation.

(8) Ibid 3
(9) Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northeast United States (U. S. Department of Commerce and U. S. Army Corps of Engineers, 1966)

Table A1.22 - Standard Project Flood Elevations

	Existing	Improved
T1	572	572
T2	577	577
T3	583	583
T4	588.8	588.5
T5	591	590.7
T6	597.3	597
T7	601.8	601.5
T8	605.5	605.2
T9	605.6	605.6
T10	622	622
T11	855.1	855.1
T12	885.4	885.4
B1	891.2	891.4
B2	898	898.2
B3	898	898.2
B4	896.6	896.7
B5	896.6	896.7
T13	902.0	902.5
A1	932.4	932.4
A2	961	961
A3	971.6	971.6

Table A1.23 - Standard Project Flood Damages
(Existing and Improved Conditions)

Reach	Residential	Commercial and Industrial	Public and Other
	$	$	$
T1	2,850,000	10,000	30,000
T2	580,000	10,000	410,000
T3	650,000	20,000	800,000
T4	830,000	0	660,000
T5	1,160,000	10,000	1,050,000
T6	800,000	0	365,000
T7	260,000	0	810,000
T8	368,000	10,000	305,000
T9	125,000	0	175,000
T10	14,000	0	37,500
RB1 through RB4	1,330,000	10,000	4,086,000
M1 through M6	541,500	5,000	1,057,000
T11	480,000	0	600,000
T12	1,100,000	240,000	1,500,000
B1	1,540,000	900,000	2,480,000
B2	228,000	62,000	382,000
B3	4,550,000	6,800,000	1,000,000
B4	240,000	20,000	77,500
B5	75,000	680,000	1,125,000
T13	118,000	0	114,000
A1 through A3	379,000	(1)	(1)
Total	18,445,000	12,787,000	18,981,000

(1) Included in Residential Damages

A1.61 In order to maximize the peak discharge at Alexander and Batavia, the Probable Maximum Storm was centered over the Tonawanda Creek Watershed above Alexander. This insured the PMF peak discharges at the Upper and Lower Reservoir were the highest possible to test the performance of the spillways. Discussion of the reservoirs may be found in Section A2a.

A1.62 The PMF was developed for Tonawanda Creek at Alexander and Batavia and the mouth of Little Tonawanda Creek. The local PMF hydrographs were routed in the same manner as the Standard Project Flood. The PMF peak discharge above Alexander is 81,200 cfs and the peak discharge above Batavia is 100,300. The PMF hydrographs are found on Plates A78 through A80.

A1.63 Data Needs

There is a lack of adequate streamflow and climatological data in the Tonawanda Creek Watershed. Hydrologic investigations for this study were made, using streamflow records for the gages listed in Table A1.36, to determine generalized relationships. These relationships were then used in discharge-duration-frequency, and unit hydrograph determinations for ungaged areas.

A1.64 The usage of balanced hydrographs in project design is an acceptable hydrologic method; however, they become useless in the real-time operation of the reservoirs. The following needs have been identified to enhance proper operation of the reservoirs.

a. Snow Survey Course in Tonawanda Creek Basin. Since it is desirable to accumulate at least 10 years of data before correlation analyses are made of the snow-survey data in stream flow forecasting, the failure to establish an adequate number of courses initially introduces, later on, difficulties in statistical and correlation analysis. The degree of confidence which can be expected in the forecasts would be reduced until a sufficient number of years has elapsed to establish the value of a particular snow course(10). At present, there is an insufficient number of sampling sites in the watershed to properly assess the water content of the snow. At least six sites will be added to the present survey in Western New York and the measurements will be made on a weekly basis. During periods of melt, measurements need to be taken more frequently. A snow-survey site will be located near the Attica, Linden, and Ledge Creek gages (see below) for correlation with stream records.

b. Installation of a Telemarked River Stage Gage in Ledge Creek. As discussed in paragraph A1.1, Ledge-Murder Creek is the principal contributing tributary downstream from the reservoir compound above the Barge Canal. Operation of the lower reservoir (see Section A2) will be based upon the inflow to the reservoir and the local cumulative inflow below the confluence with Ledge Creek. The installation of a gage at this site is of utmost importance for the proper operation of a reservoir and must be telemarked so that it may be queried at any time. This gage will be established as soon as possible for correlation with the snowmelt/rainfall data to assure efficient operation of the reservoirs. The location of the gage will be on Ledge

(10) Chow, Handbook of Applied Hydrology (New York: McGraw-Hill, 1964), p 10-14

Creek downstream of the confluence of Murder and Ledge Creeks but in an area unaffected by the elevation of Tonawanda Creek.

c. Relocate Alabama Gage Further Downstream Near Foote Road Bridge. The Tonawanda Creek at Alabama river-stage gate will be moved further downstream to Foote Road for security reasons and will be telemarked.

d. Establishment of a Telemarked Gage on Mud Creek. The placement of a telemarked gage on Mud Creek will indicate (along with the existing Ellicott Creek gage) the condition of downstream-tributary flooding. Experience has shown that the downstream tributaries in the basin peak well before Tonawanda Creek and these two gages will be sufficient to access the tributary conditions. Of secondary benefit, the gage will collect necessary hydrologic data for upgrading the watershed model.

e. Upgrade Present River Gages to Telemarked Status. At present, only the Tonawanda Creek at Batavia gage is telemarked. The remaining gages in the watershed (Tonawanda at Attica and Rapids along with Little Tonawanda at Linden) will be telemarked to allow river stage information to be known at any time.

f. Stage Recorders at the Reservoirs. At each reservoir, a stage recording gage with accompanying wire weight gage will be installed capable of recording stages up to PMF pool level. Since the reservoir will normally be empty, the recording gages will only be used during the operation of the reservoir. It will prove useful to have the recording gages switch on automatically at a preset level. This will preclude the possibility of the operator forgetting to activate them. A staff gage, protected from possible damage by ice or debris, will be invaluable in the event of failure of the other gages and would prevent the loss of valuable data particularly during a large flood.

g. Telemarked Rain Gages. During rainfall or rainfall/snowmelt floods, precipitation amounts and distribution will be needed to forecast stream runoff. Four telemarked rain gages (for example, the Fischer-Porter BDT) will be placed in the basin and will allow immediate rainfall information to be known by telephone. One will be located at the Attica Sewage Treatment Plant. A structure housing the gage will have to be built and should be located such that it will not be inundated during a flood. Backwater analysis will be done to insure the safety of the gage. A gage will be located at Linden, with the possibility of locating the rain gage on top of the river-stage gagehouse as long as the gage is not affected by the wind or peripheral objects. Another will be located at the operator's shack at the Lower Reservoir and one in the Ledge-Murder Creek Watershed. Again, these may be located on the shack or gagehouse roof, if unaffected.

A1.64 First costs and average annual OM&R costs for the data system described above have been included in the Cost Estimate Section of this report.

A2. CONSIDERED RESERVOIRS

A2.1 General

Hydrologic investigations were made for this study to determine the effects of considered reservoirs on reducing flood damages in the Tonawanda Creek Watershed. This section contains the results of these investigations for two considered flood management reservoirs identified as the Upper and Lower Reservoirs of the Batavia Reservoir Compound. Hydrograph routings were made with the Upper Reservoir only and both reservoirs in place. The local inflow hydrographs developed for existing conditions were used in the routing calculations for improved conditions. The local inflow increase due to reduction in stage on Tonawanda Creek and the resultant decrease in backwater effect on the tributaries was considered minimal as stage reduction along the Tonawanda Creek main channel will be only 1 to 2 feet for most floods. The Upper Reservoir would be located near the village of Alexander, NY, and is the same structure initially described as the Upper Reservoir of the Batavia Compound in the 1976 Tonawanda Creek Feasibility Report. The Lower Reservoir would be located south of the city of Batavia. The location and dimensions of the structure are different from that described in the 1976 report. The Lower Reservoir would be located approximately one-half mile south of the Lehigh Valley Railroad with the embankment serving as the spillway at elevation 900 feet USC&GS Datum. As used in the context of this appendix, the Batavia Reservoir Compound refers to the Upper and Lower Reservoirs in their latest configuration. In subsequent appendices and in the Main Report, the compound will be referred to as the Batavia Reservoir Compound (Modified). Further discussion of the reservoirs may be found in the Main Report.

A2.2 Normally, reservoirs are operated to impound floodwaters while making releases such that the routed release combined with local inflow does not exceed damaging discharges at downstream damage centers. This policy proved possible only for floods with a return period less than 10 years for the Upper and Lower Reservoirs. For floods with a return period of approximately 10 years and greater, the reservoirs are operated as flood attenuators due to a number of constraints which limit operational flexibility.

A2.3 The term "flood attenuator" as used in the context of this report refers to the function of any considered structure in limiting releases to a specific discharge relative to downstream channel capacities or in reducing the discharge through storage of floodwaters. The Upper Reservoir will maintain a maximum outflow discharge of 2,000 cfs as long as possible until the reservoir is filled. The Lower Reservoir, due to hydraulic constraints, will not be able to limit releases to 6,000 cfs, the channel capacity through Batavia. Instead, the inflow discharges will be reduced through storage utilization.

A2.4 A number of factors were considered in arriving at this method of operation for considered structures. These factors include: social constraints, available storage and physical constraints relative to available storage, height of dikes, etc. These factors are discussed in more detail in subsequent paragraphs for each structure.

A2.5 Area-Capacity Curves

Area-capacity curves were determined for the areas upstream from the Batavia Reservoir Compound by planimetering areas within contours of a USGS quadrangle map for the area flooded and use of the prismoidal formula. These area-capacity curves are shown on Plates A81 and A82.

A2.6 Rating Curves

Tailwater and headwater rating curves for the Batavia Reservoir Compound are shown on Plates A83 and A84. The tailwater curve for the Upper Reservoir was determined by slope-area computations using cross sections obtained in the field just downstream from the prospective structure. The tailwater curve for the Lower Reservoir was determined by backwater computations from the USGS gage at Batavia. Utilizing the tailwater curves, the headwater curves were developed using the appropriate hydraulic formulae.

A2.7 Batavia Reservoir Compound, Upper Reservoir, General

The Upper Reservoir would be located in the vicinity of the Delaware Lackawanna and Western Railroad (DLWRR) near North Alexander, NY. The drainage area upstream from this structure is approximately 102 square miles. After consideration of the topography of the site, an elevation of about 924.5 was indicated as the maximum practicable water surface without consideration of freeboard requirements. Water surfaces above this elevation, including the freeboard requirements, would seriously affect the community of Alexander, NY. The capacity at this elevation from Plate A81 is 8,490 acre-feet which is equivalent to 1.6 inches of runoff. The embankment would function as a spillway at elevation 922.5 (6,750 acre-feet, 1.2 inches).

A2.8 The principal function of the Upper Reservoir is to reduce flood damages to the farmland in the area immediately downstream from its dam and slightly reduce natural stages in Batavia and the lower Tonawanda Creek watershed. The operation of the Upper Reservoir also reduces storage requirements for the Lower Reservoir. The channel capacity downstream from the Upper Reservoir is approximately 2,000 cfs under project plan conditions. This was determined from slope-area computations and field observations.

A2.9 Batavia Reservoir Compound, Upper Reservoir, Operation Procedure For Floods With Less Than a Ten-Year Recurrence Interval

For floods with less than a 10-year return period, the reservoir was operated to impound floodwaters while making releases such that the routed release combined with the cumulative local inflow, or "local cumulative," above Batavia did not exceed the channel capacity of 2,000 cfs. The local cumulative in this case is the total runoff contributed by Little Tonawanda Creek and the Tonawanda Creek local inflow between the dam and Batavia. The following is the upper reservoir operation policy for less than a 10-year return period, with the assumption of the forecasting capability limited to 9 hours, which is the approximate travel time from the gage at Attica to the

Upper Reservoir. The real time flow data from this gage will be used during actual flood operations once the recommended plan is implemented.

a. The maximum rate of change of discharge from the upper reservoir will be 700 cfs in 3 hours. This maximum rate of change was selected after studying those floods of record which had caused no serious channel degradation.

b. When the sum of inflow to the Upper Reservoir and local cumulative for Tonawanda Creek below the confluence with Little Tonawanda is less than 1,500 cfs, all gates will be fully open (inflow = outflow).

c. When the inflow is greater than or equal to 1,000 cfs and the sum of the inflow and the local cumulative is greater than or equal to 1,500 cfs maintain 1,000 cfs outflow.

d. When inflows are 4,000 cfs for more than a few time periods, release 2,000 cfs. Maintain that release until outflows recede naturally to less than 2,000 cfs.

e. When inflows are receding and the local cumulative is less than 500 cfs, release 1,500 cfs as long as possible.

A2.10 Plates A52 and A53 present the existing and improved hydrographs for the Upper Reservoir for the 2-year flood. Plate A54 shows the operation of the Upper Reservoir for the 2-year flood using the policy from paragraph A2.9. Initially, the gates were fully opened, allowing the inflow to pass through the reservoir naturally. At time = 120 hours, the outflow was held at 1,000 cfs in accordance with rule A2.9c as the local cumlative was increasing above 500 cfs. This release was maintained until 180 hours when the outflow was increased to 2,000 cfs to facilitate lowering the pool during the period of low local cumulative. This discharge at 240 hours began to recede naturally because of the low pool level. The inflow then began to increase along with the local cumulative so that at time = 288 hours, the outflow was held at 1,000 cfs until it receded naturally.

A2.11 The results of this operational procedure for the 2-year flood are summarized in Table A2.1. An example explaining proper interpretation of the data in columns F, G, and H is provided in footnote 6. The difference between columns G and F represents the decrease in duration of direct flooding due to operating the Upper Reservoir. The difference between columns H and F represents the increase in duration of channel capacity discharge due to operating the Upper Reservoir. Table A1.13 gives the peak discharges for selected stream locations along Tonawanda Creek for the 2-year flood with the Upper Reservoir in place. Plates A55, A56, and A58 demonstrate the effect the Upper Reservoir has on the 2-year flood hydrographs at Batavia and the confluence with Ledge Creek.

TABLE A2.1 - RESULTS OF UPPER RESERVOIR OPERATION, BALANCED FLOODS

RETURN PERIOD OF FLOOD YEARS	A INFLOW PEAK DISCHARGE CFS	B OUTFLOW PEAK DISCHARGE CFS		C MAXIMUM POOL ELEVATION FEET (1)		D AREA FLOODED AT MAXIMUM POOL ACRES (2)		E CAPACITY AT MAXIMUM POOL ACRE-FT (2)		F DURATION OF FLOOD NATURAL CONDITIONS	G DURATION OF CONTROLLED FLOOD	H DURATION OF CHANNEL CAPACITY DISCHARGE
NAT and IMP	NAT and IMP	NAT	IMP	NAT	IMP	NAT	IMP	NAT	IMP	(3) (6) DAYS	(4) (6) DAYS	(5) (6) DAYS
SPF	38800	38500	38600	923.8	924.5	930	980	7900	8490	4.5 (2.4)[7]	1.4	10.3 (4.0)[7]
500	15000	12200	12200	917.6	922.5	520	850	3510	6750	3.6	1.5	8.8
200	14000	11400	11400	917.1	922.5	500	850	3250	6750	3.3	1.4	7.8
100	12500	10400	10400	916.4	922.5	470	850	2870	6750	3.1	1.3	7.3
50	11200	9440	9350	915.8	922.5	430	850	2550	6750	3.0	1.1	7.0
20	9600	8450	4740	914.9	922.5	390	850	2160	6750	2.6	1.0	6.0
10	8300	7400	3550	914.1	922.5	320	850	1840	6750	2.5	1.0	4.1
2	5000	4571	1500	911.7	920.9	240	740	1046	5480	1.0	0	0

(1) Elevations are referred to United States Coast and Geodetic Survey U.S.C. & G.S., datum.

(2) Area and Capacity determined from Plate A31 for maximum pool area and storage.

(3) Refers to the number of days the discharge is EQUAL to or GREATER THAN the downstream channel capacity of 2000 cfs for natural conditions without structure. [Same as GREATER THAN case].

(4) Refers to the number of days the discharge is GREATER THAN the downstream channel capacity of 2000 cfs for improved conditions with structure.

(5) Refers to the number of days the discharge is EQUAL to or GREATER THAN the downstream channel capacity of 2000 cfs for improved conditions with structure.

(6) An example for interpreting Columns F, G, and H is as follows: For the 200-year flood the duration of direct flooding, as shown in column F would be 3.3 days for natural conditions. With the structure, the duration of flooding would be only 1.4 days as shown in column G. The area downstream from the dam would therefore be subject to damaging discharges for only 1.4 days instead of 3.3 days. However, column H indicates that, due to the operation the duration of harmful conditions would be 7.8 days or 4.5 days longer than natural conditions.

(7) Includes the time needed to drain the volume of runoff from the pool which was assumed to precede the SDF runoff for SDF considerations. Number in ( ) is SPF runoff only.

A2.12 Batavia Reservoir Compound, Upper Reservoir, Operation Procedure For Floods With a 10-Year Recurrence Interval or Greater

For this scenario, the Upper Reservoir was operated as a flood attenuator with a limiting release of 2,000 cfs. In operating the structure for a given balanced hydrograph, inflows less than 2,000 cfs were allowed to pass with only natural storage affecting outflow. When the inflow exceeded 2,000 cfs, the structure was operated to limit the release to 2,000 cfs until the pool level reached the elevation of the overflow section. From this point, the flood control gates were operated such that inflow equalled outflow until the inflows fell below 2,000 cfs. The outflow was then held at 2,000 cfs until the pool emptied. For floods with return periods between 10 and 100 years, the flood control gates could be operated to pass inflow equal to outflow once the pool level reached the crest of the overflow section without overtopping. Floods in excess of the 100-year flood, up to the PMF, would result in overtopping the spillway.

A2.13 The results of operating the Upper Reservoir for the 200-year balanced flood are shown on Plate A42. During the beginning of the flood, inflows less than 2,000 cfs (the damaging discharge above Batavia) were allowed to pass with only natural storage affecting outflow. When the inflow exceeded 2,000 cfs, the outflow was then regulated to a maximum discharge of 2,000 cfs. Once the elevation of the pool reached 922.5, the gates were fully opened and water began to pass over the spillway with inflow essentially equalling outflow. As the flood recessed and the pool elevation became lower than the spillway crest, the outflow was then held at 2,000 cfs until the pool emptied. The outflow discharge hydrograph resulting from this operational procedure is shown on Plate A42. Plate A43 shows the 200-year stage-hydrograph resulting from operation of the Upper Reservoir for the 200-year balanced inflow hydrograph. Also shown is the 200-year pool stage-hydrograph resulting from routing the 200-year inflow hydrograph through natural storage assuming no Upper Reservoir. Plates A44 through A51 show the remaining flood hydrographs for the 200- and 50-year flood following this operation policy. Tables A1.7 through A1.12 present the peak discharges resulting from operating the Upper Reservoir for the balance hydrographs. Table A2.1 summarizes the results of this operation procedure.

A2.14 During the 18 and 19 March 1980 meeting at the Buffalo District Office with NCD, it was suggested that in order to make the operation of the reservoirs practical, the gate settings should be made as a function of reservoir stage and local (downstream) flows and not as a function of inflow to the project. It is customary policy to operate small reservoirs such as the Batavia Reservoir Compound as a function of inflow, change in storage and downstream discharges. For example, the Corps of Engineers Mt. Morris Dam is operated based upon the actual and predicted discharges at Portageville (inflow to reservoir) along with change of storage in the reservoir. During Tropical Storm Agnes 1972, the Portageville gage was washed out and a reverse storage routing through the reservoir was made so that the inflow would be known at all times and future inflows could be predicted.

A2.15 There was also concern regarding operation policy selection. It is well known that the majority of flooding in the Tonawanda Creek Watershed

is caused by snowmelt or rainfall/snowmelt. The snowpack water equivalent will be known from data gathered along the snow course in the basin. Communication with the Weather Bureau will be maintained in order that weather forecasts will be known. This will leave sufficient lead time before any actual flooding occurs. From this information the flood potential will be known allowing selection of the operation plan. For the purpose of this report, a "misoperation" was assumed for the 10-year balanced hydrograph routings. The reservoirs were operated initially using the "forecasting" (less than 10-year flood) policy but then switched to the "no-forecasting" (10-year flood and greater) policy. This proved to be conservative hydrologically and economically, i.e., benefits would not be overstated.

A2.16 <u>Batavia Reservoir Compound, Operation of Upper Reservoir For Floods of Record</u>

In this scenario, the Upper Reservoir was operated for the September 1977 and March 1978 floods using the Section A2.9 "forecasting" policy. The resulting hydrographs may be found on Plates A63 through A71 and a summation of the resulting discharges in Tables A1.15 and A1.16. Table A2.2 recapitulates the results of the Upper Reservoir operation. The March 1960 flood was not analyzed as inflow to the reservoir was not known for that event.

A2.17 Three factors were considered in selecting 922.5 as the elevation of the crest of the overflow section. These factors include (1) degree of protection and frequency of overtopping; (2) cost of embankment; and (3) SDF considerations. First, as previously mentioned, floods with return periods of 10 years or less would be controlled, thereby providing 10-year protection to the farmland just downstream from the structure. The degree of protection might be higher, but has not been determined, for summer time floods as the predominance of high-volume-peak floods occur during late winter and early spring. Secondly, due to the width of the flood plain, approximately 5,600 feet of embankment would be needed for the structure. The cost of the embankment therefore is directly related to elevation. Thirdly, SDF considerations dictated that the maximum permissible pool elevation of 924.5 not be exceeded in operating the structure for the SPF, selected as the SDF. After due consideration of these factors, an elevation of 922.5 was selected as the elevation of the 5,600-foot long overflow section.

A2.18 <u>Batavia Reservoir Compound, Upper Reservoir, Spillway Design Flood, SDF</u>

As mentioned in paragraphs A1.54 through A1.58, the Standard Project Flood, SPF, was selected as the Spillway Design Flood, SDF, for the Upper Reservoir. This was considered reasonable as the reservoir is only approximately 15 feet high from flood plain level to crest of overflow section, storage at maximum pool level is only 8,500 acre-feet, and the difference between the headwater and tailwater elevations during the routing of the SDF was found to be only about 9.9 feet.

A2.19 In developing a SDF for large reservoirs where the flood control pool extends for miles upstream, the natural conditions unit hydrograph peak

TABLE A2.2 - RESULTS OF UPPER RESERVOIR OPERATION, FLOODS OF RECORD

FLOOD	A INFLOW PEAK DISCHARGE CFS	B OUTFLOW PEAK DISCHARGE CFS		C MAXIMUM POOL ELEVATION FEET		D AREA FLOODED AT MAXIMUM POOL ACRES		E CAPACITY AT MAXIMUM POOL ACRE - FT		F DURATION OF FLOOD NATURAL CONDITIONS	G DURATION OF CONTROLLED FLOOD	H DURATION OF CHANNEL CAPACITY DISCHARGE
NAT and IMP	NAT and IMP	NAT	IMP	NAT	IMP	NAT	IMP	NAT	IMP	(3) (6) DAYS	(4) (6) DAYS	(5) (6) DAYS
MAR '60	xxx	xxx	xxx	NO	DATA	AVAIL	ABLE	xxx	xxx	xxx	xxx	xxx
SEPT '77	8640	7320	2000	914.0	921.7	340	790	1700	5920	2.6	0	1.5
MAR '78	3740	2820	1500	909.5	919.0	160	620	600	4100	1.0	0	0

(1) Elevations are referred to United States Coast and Geodetic Survey U.S.C. & G.S., datum.

(2) Area and Capacity determined from Plate A81 for maximum pool area and storage.

(3) Refers to the number of days the discharge is EQUAL to or GREATER THAN the downstream channel capacity of 2000 cfs for natural conditions without structure. [Same as GREATER THAN case].

(4) Refers to the number of days the discharge is GREATER THAN the downstream channel capacity of 2000 cfs for improved conditions with structure.

(5) Refers to the number of days the discharge is EQUAL to or GREATER THAN the downstream channel capacity of 2000 cfs for improved conditions with structure.

(6) An example for interpreting Columns F, G, and H is as follows: For the SEPT, '77 flood the duration of direct flooding, as shown in column F would be 2.6 days for natural conditions. With the structure, the duration of flooding would be eliminated as shown in column G. The area downstream from the dam would therefore not be subject to damaging discharges for this flood. However, column H indicates that, due to the operation the duration of bankful conditions would be 1.5 days or 1.1 days less than natural conditions.

is increased and time of concentration decreased. This is done to account for the loss of natural valley storage and translation of the flood wave instantaneously through the reservoir pool. For the Upper Reservoir, the flood pool would only extend approximately 1.5 miles upstream at the maximum permissible pool elevation of 924.5. This represents a 5 percent increase in pool surface area when compared with the natural pondage. The reduction of available natural storage and decrease in time of concentration would not be expected to decrease enough to warrant modifying the Upper Reservoir unit hydrograph. In light of the above, the 3-hour unitgraph for Tonawanda Creek at Alexander, shown on Plate A36 for natural conditions, was used in determining the SDF for the Upper Reservoir.

A2.20 Two starting pool elevations for the Upper Reservoir were used in routing the SPF. Routing the SPF through an empty pool resulted in a peak outflow of 38,600 cfs at a maximum pool elevation of 924.5 and a tailwater elevation of 920.0. The 38,800 cfs represents 10,700 cfs discharging through the flood control gates with the remainder passing over the spillway. Beginning the routing with a full pool (elevation = 922.5) resulted in a peak outflow discharge of 38,800 cfs. Table A1.20 lists results of these routings. Headwater and tailwater rating curves are shown on Plate A83.

A2.21 Batavia Reservoir Compound, Lower Reservoir, General

The Lower Reservoir would be located approximately one-half mile upstream of the Lehigh Valley Railroad near the southerly limit of the city of Batavia. The drainage area upstream from this structure is approximately 171 square miles. After consideration of the topography of the site, an elevation of about 903 was indicated as the maximum practical water surface elevation without consideration of freeboard requirements. The capacity at this elevation is 24,000 acre-feet which is equivalent to 2.6 inches of runoff. The field surveys taken in the Lower Reservoir area in Winter 1977-78, coupled with a cursory hydraulic analysis, indicated that the previous (1976 report) location of the emergency spillway was impossible. Instead, under the latest plan, the embankment would function as a spillway at elevation 900 feet (15,500 acre-feet, 1.7 inches).

A2.22 The function of the Lower Reservoir, in combination with the Upper Reservoir, is to reduce damages in the city of Batavia and the lower Tonawanda Creek Watershed. The channel capacity in the city of Batavia is approximately 6,000 cfs, determined from the USGS rating curve at the Batavia gage and backwater computations.

A2.23 Batavia Reservoir Compound, Lower Reservoir, Operation Procedure For Floods With Less Than a 10-Year Recurrence Interval

For floods with less than a 10-year return period, the prospective reservoir would be operated to impound floodwaters while making releases such that the routed release, combined with local cumulative below the confluence with Ledge Creek, did not exceed the channel capacity of 3,000 cfs. The local cumulative in this case is the local runoff contributed by Murder-Ledge Creek and the Tonawanda Creek local inflow between the dam and the confluence with Ledge Creek. There is an 18-hour delay between the time that the release is

made and the time it reaches the confluence with Ledge Creek. It is usually necessary to match current releases with the local flows expected to occur at the damage center at a travel time later. Since a 9-hour forecast capability was assumed, there is no time for advance warning.

A2.24 The following is the Lower Reservoir operation policy for floods with less than a 10-year return period:

a. Maximum rate of change of discharge will be 700 cfs in 3 hours.

b. When the sum of inflow to the Lower Reservoir and local cumulative for Tonawanda Creek below the confluence with Ledge Creek is less than 2,000 cfs, gates will be fully open. Inflow is allowed to pass through naturally.

c. When the sum of inflow and local cumulative is greater than 2,000 cfs and less than 5,000 cfs, maintain a 1,000 cfs release.

d. When the sum of inflow and local cumulative is greater than 5,000 cfs, release 2,000 cfs.

e. When emptying the pool (peak has passed), and the sum of inflow and local cumulative is less than 1,500 cfs and the local cumulative is less than or equal to 500 cfs release 2,000 cfs.

A2.25 Plates A55 and A56 present the existing and improved hydrographs for the Lower Reservoir for the 2-year flood. Plate A57 shows the operation of the Lower Reservoir for the 2-year flood using the policy from paragraph A2.24. Initially, the gates were fully opened, allowing the inflow to pass through the reservoir naturally. At 126 hours, the outflow was held at 1,000 cfs as the local cumulative and inflow were greater than 2,000 cfs. This release was maintained until 252 hours when the outflow was increased to 2,000 cfs to facilitate lowering the pool during the period of low local cumulative. At 285 hours, the outflow was decreased to 1,000 cfs to store the increasing inflow to the reservoir. The event terminated with a steady outflow of 2,000 cfs to drain the pool.

A2.26 The results of this operational procedure for this 2-year flood are summarized in Tables A2.3 and A2.4. Table A1.13 gives the peak discharges for selected stream locations along Tonawanda Creek for the 2-year flood with both reservoirs in place. Plate A58 demonstrates the effect the Reservoir Compound has on the 2-year flood hydrograph at the confluence with Ledge Creek.

A2.27 <u>Batavia Reservoir Compound, Lower Reservoir, Operation Procedure For Floods With a 10-Year Recurrence Interval or Greater</u>

The operation procedure for the balanced hydrograph routings simply involved maintaining the Lower Reservoir gates in full open position. The inflow was attenuated by the storage behind the structure. Operating the structure in this manner resulted in the spillway being overtopped for floods in excess of the 500-year flood.

Table A2.3 - Results of Operation for the Lower Reservoir, Batavia Reservoir Compound, Balanced Floods

Return Period of Flood	A Inflow Peak Discharge CFS			B Outflow Peak Discharge CFS			C Maximum Pool Elevation Feet (1)			D Area Flooded at Maximum Pool Acres (2)			E Capacity at Maximum Pool Acre-Ft (2)		
	(3) Nat	(4) Imp. A	(5) Imp. B	(3) Nat	(4) Imp. A	(5) Imp. B	(3) Nat	(4) Imp. A	(5) Imp. B	(3) Nat	(4) Imp. A	(5) Imp. B	(3) Nat	(4) Imp. A	(5) Imp. B
SPF	49200	50200	50200	28500	28500	28400	902.0	902.0	902.5	5150	5150	3050	39500	39500	23500
500	17200	17200	17200	9850	8400	6000	896.7	895.7	900.0	2660	2350	2560	14500	12100	15500
200	16000	16000	16000	9100	7540	5780	896.2	895.2	899.2	2470	2180	2300	13300	11000	13400
100	14700	14000	14000	8470	6770	5450	895.8	894.6	898.3	2350	2020	2020	12400	9700	11700
50	13700	10000	10000	7730	5930	5240	895.4	893.9	897.3	2250	1850	1750	11500	8200	9680
20	11700	6930	6930	6650	4930	4620	894.6	893.0	895.9	2020	1600	1400	9700	6900	7410
10	10300	6000	6000	5870	4320	4260	893.9	891.9	895.1	1850	1350	1220	8200	5200	6600
2	6310	3410	3410	3890	2530	2000	891.8	889.4	892.0	1340	770	1950	5000	2500	10700

(1) Elevations are referred to United States Coast and Geodetic Survey, U.S.C. & G.S., Datum.

(2) Area and Capacity Determined from Plate A82 for Maximum Pool Elevation, column C

(3) Nat. refers to natural conditions with no structures.

(4) Imp. A refers to improved conditions with the Upper (Alexander) Reservoir Only

(5) Imp. B refers to improved conditions with the Batavia Reservoir Compound.

TABLE A2.4 — RESULTS OF OPERATION FOR THE LOWER RESERVOIR, BATAVIA RESERVOIR COMPOUND, BALANCED FLOODS

Return Period of Flood	A Outflow Peak Discharge CFS			B Maximum Pool Elevation Feet			C Duration of Flood Natural Conditions Days (1) (3)		D Duration of Controlled Flood - Imp. A Days (2) (3)		E Duration of Controlled Flood - Imp. B Days (2) (3)	
Years	(4) Nat	(5) Imp. A	(6) Imp. B	(4) Nat	(5) Imp. A	(6) Imp. B	Outflow Discharge	Pool Elevation	Outflow Discharge	Pool Elevation	Outflow Discharge	Pool Elevation
SPF	28500	28500	28400	902.0	902.0	902.5	5.5 (2.9)[7]	15.5 (4.4)[7]	5.5 (3.0)[7]	15.5 (4.2)[7]	5.5 (3.1)[7]	15.5 (5.4)[7]
500	9850	8400	6500	896.7	895.7	900.0	1.8	8.6	1.5	10.1	0.5	10.8
200	9100	7540	5780	896.2	895.2	899.2	1.5	7.3	1.3	8.4	0	9.8
100	8470	6770	5450	895.8	894.6	898.3	1.4	4.9	0.9	8.1	0	8.3
50	7730	5930	5240	895.4	893.9	897.3	1.1	4.3	0	7.6	0	8.1
20	6650	4930	4620	894.6	893.0	895.9	0.8	3.3	0	6.1	0	6.8
10	5870	4320	4260	893.9	891.9	895.1	0	3.0	0	3.1	0	5.1
2	3270	2530	2000	891.8	889.4	892.0	0	2.4	0	1.3	0	9.8

(1) Refers to the number of days the outflow discharge and pool elevation are EQUAL TO or GREATER THAN the channel capacity discharge of 6,000 cfs at Batavia and the elevation corresponding to a channel capacity discharge of 2,000 cfs in the pool area respectively for natural conditions without improvements.
(2) Refers to the number of days the outflow discharge and pool elevation are EQUAL TO or GREATER THAN the channel capacity discharge of 6,000 cfs at Batavia and the elevation corresponding to a channel capacity discharge of 2,000 cfs in the pool area respectively for improved conditions (Imp. A or Imp. B).
(3) An example for interpreting columns C through E is as follows: Column C shows for the 200-year flood that the duration of flooding in the city of Batavia would be 1.5 days and the duration of flooding in the pool area would be 7.3 days for natural conditions without any structures. Column D shows that with the Upper (Alexander) Reservoir flooding in the city of Batavia would be 1.3 days and the duration of flooding in the pool area would be 8.4 days. Column E shows that in operating the Batavia Reservoir compound flooding in the city of Batavia has been eliminated for this flood and that the duration of flooding in the pool area would be 9.8 days.
(4) Nat. refers to natural conditions with no structures.
(5) Imp. A refers to improved conditions with the Upper (Alexander) Reservoir only.
(6) Imp. B refers to improved conditions with the Batavia Reservoir Compound.
(7) Includes the time needed to drain the volume of runoff from the pool which was assumed to proceed the SDF runoff for SDF considerations. The SDF for this reservoir is discussed in paragraph A2.30 through A2.32. Number in ( ) is SPF runoff only.

A2.28 The results of operating the Reservoir Compound for the 200- and 50-year balanced floods are shown on Plates A42 through A51. Tables A1.7 through A1.12 present the peak discharges resulting from operating the Reservoir Compound for the balance hydrographs. Tables A2.3 and A2.4 summarize the results of the operation procedure. An example explaining the interpretation of columns C, D, and E of Table A2.4 is provided in footnote 3. The difference between columns D and C represents the decrease in duration of direct flooding and increase in duration of pool elevation in the Lower Reservoir area due to operating the Upper Reservoir. The difference between columns E and C represents the decrease in duration of direct flooding and increase in duration of pool elevation in the Lower Reservoir area due to operating the Reservoir Compound. The difference between columns E and D represents the effect of operating the Reservoir Compound over the Upper Reservoir alone. The outflow discharges (existing and improved) from Table A2.4 and the stage-discharge curves (Plates A113 and A115-117) along with limited topographic information were used to construct the approximate 100-year flooded outlines in the city of Batavia for with and without project conditions as shown on Plate A1d.

A2.29 Batavia Reservoir Compound, Operation of Lower Reservoir For Floods of Record

In this scenario, the Lower Reservoir was operated for the September 1977 and the March 1978 floods using the Section A2.23 forecasting policy. Further discussion on the operation policy for a rare summertime flood such as the September 1977 flood is presented in paragraph A2.35 through A2.38. Operating the Batavia Reservoir Compound for the September 1977 flood resulted in filling the Lower Reservoir, whereas the peak level was 2.8 feet below the spillway crest for the March 1978 flood. Due to the magnitude of the March 1960 flood, the policy described in Section A2.27 was used. Under this operation policy, the maximum elevation obtained in the Lower Reservoir was 1.2 feet below the crest of the spillway. The resulting hydrographs may be found on Plates A59 through A71 and a summation of the resulting discharges for the entire watershed in Tables A1.14 through A1.16. Tables A2.5 and A2.6 present the results in the Lower Reservoir area for the floods of record.

A2.30 Batavia Reservoir Compound, Lower Reservoir Spillway Design Flood SDF

As mentioned in paragraphs A1.54 through A1.58 , the Standard Project Flood, SPF, was selected as the SDF for the Lower Reservoir. This was considered reasonable and conservative after reviewing associated regulations and reviewing the research literature. The Lower Reservoir is only approximately 10 feet high from flood plain to top of overflow sections, storage at maximum pool level is only 23,500 acre-feet, and the difference between headwater and tailwater elevations during the routing of the SDF was found to be negligible.

A2.31 As mentioned previously, in developing a SDF for large reservoirs where the flood pool extends for miles upstream, the natural conditions unit hydrograph peak is usually increased and the time of concentration decreased.

TABLE A2.5 – RESULTS OF OPERATION FOR THE LOWER RESERVOIR, BATAVIA RESERVOIR COMPOUND, FLOODS OF RECORD

FLOOD	A INFLOW PEAK DISCHARGE CFS			B OUTFLOW PEAK DISCHARGE CFS			C MAXIMUM POOL ELEVATION FEET (1)			D AREA FLOODED AT MAXIMUM POOL ACRES (2)			E CAPACITY AT MAXIMUM POOL ACRE-FT (2)		
	(3) NAT	(4) IMP. A	(5) IMP. B	(3) NAT	(4) IMP. A	(5) IMP. B	(3) NAT	(4) IMP. A	(5) IMP. B	(3) NAT	(4) IMP. A	(5) IMP. B	(3) NAT	(4) IMP. A	(5) IMP. B
MAR '60	11020 (7)	— (6)	11020 (7)	7200	— (6)	5610 (8)	894.7	— (6)	898.8	2050	— (6)	2170	10000	— (6)	12700
SEPT '77	10800	6860	6860	5110	3720	2000	893.1	891.2	899.5	1650	1200	2400	7000	4200	14200
MAR '78	5630	4070	4070	3740	2930	2000	891.5	890.4	897.2	1270	1000	1710	4500	3500	9440

(1) Elevations are referred to United States Coast and Geodetic Survey, U.S.C. & G.S., Datum.
(2) Area and Capacity Determined from Plate A82 for Maximum Pool Elevation, column C
(3) Nat. refers to natural conditions with no structures.
(4) Imp. A refers to improved conditions with the Upper (Alexander) Reservoir Only
(5) Imp. B refers to improved conditions with the Batavia Reservoir Compound.
(6) Data not available
(7) Inflow obtained by reverse-routing hydrograph at Batavia gage (existing)
(8) Routings begin with inflow to lower reservoir and hence do not show effect of upper reservoir

TABLE A2.6 — RESULTS OF OPERATION FOR THE LOWER RESERVOIR, BATAVIA RESERVOIR COMPOUND, FLOODS OF RECORD

FLOOD	A OUTFLOW PEAK DISCHARGE CFS			B MAXIMUM POOL ELEVATION FEET			C DURATION OF FLOOD NATURAL CONDITIONS DAYS (1) (3)		D DURATION OF CONTROLLED FLOOD - IMP. A DAYS (2) (3)		E DURATION OF CONTROLLED FLOOD - IMP. B DAYS (2) (3)	
YEARS	(4) NAT	(5) IMP. A	(6) IMP. B	(4) NAT	(5) IMP. A	(6) IMP. B	OUTFLOW DISCHARGE	POOL ELEVATION	OUTFLOW DISCHARGE	POOL ELEVATION	OUTFLOW DISCHARGE	POOL ELEVATION
MAR'60	7200	—	5610	894.7	—	898.8	1.0	4.0	—	—	0	4.0
SEPT'77	5110	3720	2000	893.1	891.2	899.5	0	3.6	0	3.4	0	10.2
MAR'78	3740	2930	2000	891.5	890.4	897.2	0	2.4	0	2.0	0	6.3

(1) Refers to the number of days the outflow discharge and pool elevation are EQUAL TO or GREATER THAN the channel capacity discharge of 6,000 cfs at Batavia and the elevation corresponding to a channel capacity discharge of 2,000 cfs in the pool area respectively for natural conditions without improvements.
(2) Refers to the number of days the outflow discharge and pool elevation are EQUAL TO or GREATER THAN the channel capacity discharge of 6,000 cfs at Batavia and the elevation corresponding to a channel capacity discharge of 2,000 cfs in the pool area respectively for improved conditions (Imp. A or Imp. B).
(3) An example for interpreting columns C through E is as follows: Column C shows for the Sept.'77 flood that the duration of flooding in the city of Batavia would be 0 days and the duration of flooding in the pool area would be 3.6 days for natural conditions without any structures. Column D shows that with the Upper (Alexander) Reservoir flooding in the city of Batavia would be 0 days and the duration of flooding in the pool area would be 3.4 days. Column E shows that in operating the Batavia Reservoir compound flooding in the city of Batavia has been eliminated for this flood and that the duration of flooding in the pool area would be 10.2 days.
(4) Nat. refers to natural conditions with no structures.
(5) Imp. A refers to improved conditions with the Upper (Alexander) Reservoir only.
(6) Imp. B refers to improved conditions with the Batavia Reservoir Compound.

This is done to account for the loss of natural valley storage and translation of the flood wave instantaneously through the reservoir. For the Lower Reservoir, however, this was not done. The operating plan for the Lower Reservoir was developed to minimize increases in depth and duration of flooding in the pool area for most floods. This applied to the SPF (which is the SDF for the Lower Reservoir) as well, so the extent of the flood control pool would be the same as for natural conditions and would not require modifying the natural conditions unit hydrographs. In light of the above, the 3-hour unit hydrographs for Tonawanda Creek at Alexander and Tonawanda Creek local area, Alexander to Batavia, shown on Plate A36 for natural conditions, were used in determining the SDF for the Lower Reservoir.

A2.32 With the gates of the Lower Reservoir fully open, the SDF was routed through the reservoir assuming two starting water surface elevations, empty and full pool condition. Results of these routings can be found on Table A1.20. Routing the SDF with a peak inflow of 50,200 cfs resulted in a peak outflow of 28,400 cfs (6,000 cfs through gates, remainder over spillway) at elevation 902.5 with a full pool starting condition. At elevation 902 feet, the tailwater curve controls the discharge passing over the spillway. The tailwater curve used can be found on Plate A84 which assumes the Lehigh Valley Railroad Bridge washed out under existing conditions and removed under improved conditions. The SPF flooded area in Batavia will be the same under existing or improved conditions. The 28,400 cfs SPF discharge in Batavia was used with the stage-discharge curves (Plates A113 and A115-A117) and the limited topographic information available to construct the approximate SPF flooded area in the city of Batavia as shown on Plate A1d.

A2.33 Batavia Reservoir Compound, Flooding Downstream of Rapids

Tables A1.7 through A1.16 present the results of the balanced hydrograph and flood of record routings for the entire watershed. Improved conditions discharge-frequency curves were derived using these tables and are shown on Plate A15a. The frequency curves for Tonawanda Creek at Rapids and at the confluence with Mud Creek include the diversion to Mud and Black Creeks. Plates A46, A51, A58, A61, and A71 exhibit the existing and improved hydrographs at the confluence with Ledge Creek. As can be seen in Table A2.7, the impact of the reservoirs on the downstream discharges decreases in a downstream direction both in percentage and net reduction. For example with the proposed reservoirs in operation, the 50-year discharge at Batavia would be reduced by 32 percent. The influence of the Reservoir Compound on the discharge reduces downstream until at the confluence with Ransom Creek the discharge reduction is only 14 percent. The modeling results using the March 1978 flood also substantiate this fact as the peak discharge reduction would be 47 percent at Batavia but only 25 percent at Rapids. The table also demonstrates the decrease in effectiveness of the project as the flood magnitude increases which is mainly due to the limited storage capacity of the reservoirs. The substantial reduction in peak discharge at Batavia (49 percent) for the 2-year flood is due to the operation policy for the small floods (less than 10-year) which effectively utilizes the storage of the reservoirs.

Table A2.7 - Peak Discharge Reduction With Reservoirs in Operation

Location	Percent Reduction in Peak Discharge			
	500-Year	50-Year	2-Year	March 1978
Tonawanda at Batavia	32	32	49	47
Tonawanda at Alabama	28	25	48	26
Tonawanda at Rapids	16	17	40	25
Tonawanda at Confluence with Mud Creek	14	15	37	-
Tonawanda at Confluence with Ransom Creek	14	14	32	-

A2.34 Table A2.8 presents the duration of flooding at Rapids, NY. As shown, the 2-year flood at Rapids under existing conditions would discharge overbank for 1.9 days. With the Upper Reservoir alone, the duration of flooding would be reduced to 0.9 day whereas with the Batavia Reservoir Compound in operation, the flooding would be eliminated. Tonawanda Creek overflow to Mud and Black Creek would also be eliminated for the 2-year flood with the Batavia Reservoir Compound. Depths from floods with intermediate return periods would be about the same with the Upper Reservoir alone or with the Batavia Reservoir Compound and would reflect a one-half foot decrease compared with existing conditions. For floods with a large return period, the duration of flooding would increase slightly with the structures in place. The discharge would decrease approximately 3 percent with the Upper Reservoir only and 5 percent with the compound in place compared to existing conditions.

A2.35 Summertime Operation of the Reservoirs

An analysis of the Tonawanda Creek at Batavia Gage for the 25-year record, 1945-1970, indicated that 90 percent of the peaks above base (1,800 cfs) occurred between the period 1 November - 14 April. As explained in paragraph A1.5, the majority of the floods occurring in the Tonawanda Creek basin are due to snowmelt. Time and cost constraints did not allow the consideration of a seasonal analysis and hence attention was focused on an annual series frequency analysis. The operation policy for the reservoirs for snowmelt and rainfall/snowmelt flooding has proven to be effective in flood damage reduction in the watershed. For rainfall events occurring in late spring and summer, a different operation policy for the reservoirs will be enacted. Further refinement of this policy will be completed during Advanced Engineering and Design Analysis through cooperation with SCS personnel, affected landowners, and the Corps. This policy will reflect the attempt to reduce damages in a manner fair to all parties concerned.

A2.36 Operation of the Batavia Reservoir Compound has shown that it can take over 1 week longer to empty the Lower Reservoir than under natural conditions. Traditionally, the farmers in this area need 1 or 2 weeks to allow the fields to drain before they are able to begin preparing their land. The construction of the reservoirs will not shorten this local area drainage

time. Further, storing water in the Lower Reservoir after 15 April could have an effect on the farming practices in that area.

A2.37 A summer operation plan was developed for small floods (approximately of 2-year annual peak discharge or less) which would lessen flooding in the Lower Reservoir area and to a minor extent areas downstream of Batavia. Outflows from the Upper Reservoir would basically be maintained at 500 cfs unless a large storm would occur. In that case, the operation would switch to the "winter" (snowmelt) operation policy. The gates in the Lower Reservoir would remain fully open. Recently (14 September 1979) the Tonawanda Basin experienced a large rainfall event with almost 5" of rain recorded at the Buffalo Airport in 13 hours. Field observations indicated that downstream local drainage areas and tributaries peaked well before the main stem. This was confirmed by a 700 cfs reduction in peak discharge between Alabama and Rapids. Following the summertime operation plan, much of the overbank flooding in the lower portion area of the Lower Reservoir area would have been reduced. Flows would have been well within bank below the Upper Reservoir and above the confluence with Little Tonawanda Creek. Overbank flooding would have been reduced downstream of the compound with the reduction in flooding decreasing as the distance from the compound increased.

A2.38 As cited in paragraph A2.29, operating the Batavia Reservoir Compound for the September 1977 flood following the winter operation scheme would result in filling the Lower Reservoir. This summertime flood of record caused large agricultural losses throughout the basin. Filling the Lower Reservoir would have aggravated the losses in that area while alleviating damage to crops downstream of the compound. Ninety percent of the farmland in the watershed lies downstream of Batavia. Operating the Reservoir Compound using the "summer" operating policy would result in filling the Lower Reservoir to elevation 893.8 feet (outflow = 3,600 cfs) which is about 6 feet lower than if the Lower Reservoir were operated using the "winter" policy and approximately at the same elevation as natural conditions. As discussed in paragraph A2.33, refinement of the operation policy to handle these rare summertime floods will be accomplished during Advanced Engineering and Design.

A2.39 <u>Dam Failure, General</u>

During Advanced Engineering and Design, the upper and lower dam failure analyses along with flooded area maps will be completed in accordance with ER 1130-2-419, "Project Operation, Dam Operations Management Program" using a sophisticated unsteady flow model. For the purpose of this report a dam failure analysis was completed using "Flood Hydrograph Package HEC-1 for Dam Safety Investigations." The dam failure hydrograph is computed by a weir flow equation for the shape of the breach as the failure progresses with a continuous water balance computed at short time intervals throughout the simulation. The modified Puls (hydrologic) method of channel routing is utilized for routing the dam failure hydrograph. The intent in using the program was to expeditiously evaluate the effect of a dam failure on downstream stages.

Table A2.8 - Duration of Flooding at Rapids, NY

Flood	Discharge at Rapids Gage CFS 1/			Elevation at Rapids Gage Feet - USC&GS Datum 6/			Duration of Flood - Days 7/		
	NAT 2/	IMP A 3/	IMP B 4/	NAT	IMP A	IMP B	NAT	IMP A	IMP B
SPF 5/	37,600	-	36,700	598.1	-	593.9	5.0	-	5.9
500-Year	6,970	6,830	6,600	589.6	589.4	588.8	9.8	10.1	10.0
200-Year	6,800	6,550	6,260	589.3	588.7	588.3	9.0	9.0	8.9
100-Year	6,600	6,300	6,120	588.8	588.3	587.9	5.9	7.6	7.8
50-Year	6,420	6,150	6,060	588.5	588.0	587.8	4.5	6.0	5.9
20-Year	6,050	5,770	5,730	587.8	587.2	587.2	3.4	3.8	3.8
10-Year	5,820	5,560	5,540	587.3	586.8	586.8	2.8	3.1	3.1
2-Year	5,140	4,710	3,950	586.0	585.2	583.7	1.9	0.9	0
March 1978	5,220	4,870	4,560	586.2	585.6	584.8	3.9	4.8	2.6

1/ Does not include diversion to Mud and/or Black Creek, Gage at river mile 18.6.
2/ NAT refers to natural conditions with no structures.
3/ IMP A refers to improved conditions with the Upper Reservoir only.
4/ IMP B refers to improved conditions with the Batavia Reservoir Compound.
5/ Total discharge for SPF - no diversions taken.
6/ Gage Zero = 571.04 feet USC&GS Datum.
7/ Refers to the number of days the discharge is EQUAL TO or GREATER THAN the channel capacity discharge of 4,000 cfs at Rapids.

A2.40 The selection of breach parameters introduces uncertainty in the results although errors in their description are dampened as the floodwave advances downstream. For earthen dams the suggested range of possible breach widths varies between one-half and four times the height of the dam. (11) The time of failure may be in the range of one-half to 4 hours depending on the dam height, dam composition, and the extent of compaction of the materials. A conservative estimate of the dam-failure hydrograph is obtained by selecting a breach width in the uppermost range and a failure time in the lower range. The flood wave propogates often at a speed ranging from 2-10 mph.

A2.41 Batavia Reservoir Compound, Upper Dam Failure

The operation of the Upper Reservoir is discussed in paragraphs A2.7 through A2.20. During operation for the 2-year flood the Upper and Lower Reservoirs will be almost full. For this frequent event a dam failure was calculated assuming a 70.0 foot rectangular breach (approximately four times the dam height) and a 0.5 hour failure time. The dam was assumed to fail at the time of maximum pool with the gate setting remaining in a constant 1,000 cfs outflow position.

A2.42 On Plate A54a the Upper Reservoir breach hydrograph is presented. The time base of the hydrograph corresponds to that used for the 2-year flood hydrographs shown on Plates A52 through A57. The maximum outflow from the breached Upper Dam was 16,900 cfs with the reservoir taking approximately one-half day to empty.

A2.43 Since the Upper Reservoir will fill before the Lower Reservoir, there was sufficient storage in the Lower Reservoir to absorb the breach hydrograph and overtopping did not occur. The outflow hydrograph to the Lower Reservoir resulting from the Upper Dam failure combined with Little Tonawanda Creek and local inflow is presented on Plate A57a along with the reservoir stage hydrograph. The elevation of the Lower Reservoir at the time of failure of the Upper Dam was 895.0 feet and obtained a maximum elevation of 898.4 feet with 3,900 acre-feet of storage remaining below the spillway (75 percent storage utilized). It was assumed that after the failure of the Upper Reservoir the gates in the Lower Dam were not able to be changed from the constant 1,000 cfs outflow.

A2.44 No adverse affects occurred in this scenario downstream of the Reservoir Compound due to the failure of the Upper Reservoir. This is not to imply that other combinations of breach parameters and flood magnitudes could not have a greater affect than the failure mode selected. During Advanced Engineering and Design other combinations of failure conditions will be investigated.

(11) Training Notes: Analytical Techniques for Dam Break Analysis. (Davis, California, Hydrologic Engineer Center, U. S. Army Corps of Engineers, 14-18 January 1980.)

A2.45 <u>Batavia Reservoir Compound, Lower Dam Failure</u>

The Lower Dam was assumed to fail at the time of maximum pool during the operation for the 2-year flood. A 40.0-foot rectangular breach and 0.5 hour failure time was assumed. On Plate A57b the failure hydrograph and reservoir stage hydrograph are presented. The Lower Reservoir elevation is at 898.0 feet at time of failure and drops at a rate of 1 foot in 3.5 hours. The breach in the Lower Reservoir resulted in a peak outflow of 4,220 cfs.

A2.46 Routing the failure hydrograph through the railroads to Batavia resulted in a peak discharge of 3,300 cfs and a 6-hour travel time to Batavia. Because of the channel project in Batavia with a 6,000 cfs channel capacity, no flooding would occur. The discharge hydrograph in Batavia is also presented on Plate A57b.

A3. LOWER TONAWANDA, MUD, RANSOM, AND BLACK CREEK WATERSHEDS

A3.1 General

The lower Tonawanda Creek watershed comprises the reach from the mouth, at the Niagara River, upstream to Hopkins Road at Alabama, NY, a total distance of 41.5 stream miles. It also includes the areas along Mud, Ransom, and Black Creeks. The flooded area for this tract was divided into 20 damage reaches which include 10 on Tonawanda Creek (T-1 through T-10), six on Mud Creek (M-1 through M-6), and four on Ransom and Black Creeks (RB-1 through RB-4). A detailed damage reach description is included in Appendix B. These reaches are shown on Plate A1a.

A3.2 Overbank flooding on Mud, Ransom, and Black Creeks is normally caused by floodwaters from Tonawanda Creek entering these watersheds. To produce damaging stages on these tributaries, the level of Tonawanda Creek must exceed elevations on the divides between the tributary watersheds and the Tonawanda Creek main stem. Further, levels must remain above this stage for an extended length of time. In determining the stage-frequency curves for these streams, the diversion discharge from Tonawanda Creek was used. The local runoff was not included as this runoff was found to occur prior to overflow from Tonawanda Creek. A description of the diversions was discussed previously in Section A1.

A3.3 Stage-Discharge Curves, Existing Conditions

Plate A85 shows the stage-discharge curve just upstream of the Campbell Blvd. bridge. At lower discharges, the stage is highly dependent upon the Niagara River. For the purpose of this report, the rating curve was based on the mean Niagara River stage. This assumption will have minimal effect on the damage calculations as there is approximately 10,000 cfs channel capacity in this area. Plate A86 shows the discharge rating curve for the Rapids Road Gage. The curve indicating the discharge passing the gage in Tonawanda Creek is labeled "Tonawanda Creek at Rapids Gage less diversions." A stage-discharge curve for the USGS gaging station located at Hopkins Road near Alabama, NY, is shown on Plate A87. This curve was developed from discharge measurements made by the USGS up to 6,700 cfs with further extrapolation accomplished by this office.

A3.4 Stage-Frequency Curves, Existing Conditions

A partial duration stage-frequency curve for the Hopkins Road gaging station, Reach T-10, is shown on Plate A88. This curve was developed from available stage records of the New York State Department of Public Works and USGS. Stages for the 55 years of record were plotted using the Weibull Plotting Position method. A smooth curve was then drawn through these points. Also shown for comparison are stages for selected flood discharges, 500-, 200-, 100-, 20-, 10-, and 2-year floods, determined from the existing conditions discharge-frequency curve, shown on Plate A112 and the stage-discharge curve, shown on Plate A87, for the Hopkins Road Gage, Alabama, NY. A smooth curve was drawn through these points and labeled Annual Duration.

Table A3.1 - Stage-Frequency Curves, Lower Tonawanda Watershed

Rating Curve		Appropriate Discharge	Stage Frequency Curve	
Description	Plate	from Tables A1.7 - A1.13	Index Points	Plates
U.S. Campbell Blvd.	A85	Ton BLW Conf w/Ransom	T-1 thru T-3	A89 - A91
Rapids Gage	A86	Ton at Rapids less Diversions	T-4 thru T-7	A92 - A95
Hopkins Road Gage	A87	Alabama less Div. to Mud	T-8 thru T-10	A96 - A98
Mud Creek at M-3	A99	Diversion to Mud Cr.	M-1 thru M-6	A100 - A105
Ransom-Black at RB-2	A106	Diversion to Black Cr.	RB-1 and RB-2	A108 - A109
Ransom-Black at RB-4	A107	Diversion to Black Cr.	RB-3 and RB-4	A110 - A111

Table A3.2 - Existing and Improved Flooded Areas (Acres) by Return Period

Reach	500-year		200-year		100-year		50-year		20-year		10-year		2-year	
	Existing	Improved	Existing	Improved	Existing	Improved	Existing	Improved	Existing	Improved	Existing	Improved	Existing	Improved
T-3	670	220	570	130	480	50	330	0	130	0	30	0	0	0
T-4	160	70	130	10	90	0	60	0	0	0	0	0	0	0
T-5	1,670	1,450	1,550	1,290	1,500	1,220	1,410	1,130	1,120	950	1,120	650	530	0
T-6	3,600	3,380	3,500	3,210	3,400	3,150	3,320	3,070	3,180	2,900	3,030	2,630	2,550	1,000
T-7	1,480	1,400	1,450	1,260	1,420	1,060	1,370	960	1,200	760	960	500	480	0
T-8	2,180	2,020	2,160	2,000	2,150	1,930	2,110	1,890	2,000	1,740	1,890	1,550	1,400	150
T-9	1,970	1,910	1,970	1,850	1,960	1,790	1,940	1,680	1,860	1,480	1,740	1,280	1,100	0
T-10	800	750	800	730	790	690	780	630	730	240	630	150	100	0
RB-1	710	640	675	600	660	550	620	530	530	460	480	350	175	0
RB-2	2,150	1,450	1,970	1,190	1,590	1,040	1,260	970	1,000	800	800	550	400	0
RB-3	3,400	3,010	3,220	2,820	3,060	2,320	2,920	2,520	2,320	2,130	2,180	2,040	1,590	0
RB-4	1,280	1,210	1,260	1,190	1,210	1,130	1,190	1,110	1,130	1,050	1,070	980	890	0
M-1	140	70	120	60	110	60	100	50	60	30	50	10	0	0
M-2	550	530	540	530	540	520	540	520	540	500	520	440	0	0
M-3	1,500	1,150	1,440	1,070	1,380	1,000	1,260	850	1,150	400	850	0	0	0
M-4	580	340	540	310	470	290	400	240	310	150	230	70	0	0
M-5	1,270	1,100	1,220	1,070	1,200	1,050	1,170	1,000	1,070	880	990	720	280	0
M-6	1,030	1,020	1,030	1,010	1,030	1,010	1,020	990	1,020	880	990	100	0	0
T-11	2,740	1,750	2,640	1,150	2,500	780	2,330	540	1,910	0	1,250	0	0	0
T-12	270	190	260	150	250	130	240	110	200	50	160	0	0	0
Low. Res.	2,620	2,560	2,470	2,300	2,350	2,020	2,250	1,750	2,020	1,400	1,850	1,220	1,340	1,950
Upp. Res.	520	850	500	850	470	850	430	850	390	850	320	850	240	740

A3.5 In order to develop stage-frequency curves for existing conditions at the index points, the rating curves described in paragraph A3.3, Tables A1.7 - A1.13, and the 1960 flood profile were used. Highwater marks were used to establish the 1960 water surface profile. The stage-frequency curves were first developed at the stream locations of the rating curves using the appropriate discharge for the various recurrence intervals from Tables A1.7 - A1.13. The differences in stage between the 1960 flood and the stage for the 500-, 200-, 100-, 50-, 20-, 10-, and 2-year recurrence interval were calculated for the above locations. These differences were assumed applicable for a reach encompassing a few index points. Applying these differences to the 1960 flood elevation at the index points resulted in a stage-frequency curve at that location. The absence of data adequate for backwater calculations necessitated the development of the above method to calculate the stage-frequency curves. The determination of the water surface profiles would not have only insured more confidence in the stage-frequency curves but could have also been incorporated into various ongoing FIS reports for Tonawanda Creek. Study cost savings were made, but at the expense of an important aspect of the study.

A3.6 Table A3.1 lists the discharge rating curve and appropriate discharge used as the basis for calculating the stage-frequency curves at the index points. An example of calculating the 100-year stage at T-6 is as follows: From Table A1.9, it is determined that the 100-year discharge at the Rapids Gage less diversions is 6,600 cfs which corresponds to an elevation of 590.0 feet from Plate A86. This is 0.8 foot higher than the 1960 flood elevation. At index point T-6, the 1960 flood elevation was 592.5 feet, and hence the 100-year stage at T-6 is 593.3 feet as shown on Plate A94.

A3.7 Stage-Frequency Curves, Improved Conditions

Stage-frequency curves were developed for the recommended plan and are shown on Plates A89 through A98, A100 through A105, and A108 through A111, along with the stage-frequency curves for the Upper Reservoir only and existing conditions. Improved discharges were obtained by routing and combining the balanced hydrographs with the structures in place. These discharges may be found in Tables A1.7 through A1.13. Following the method explained in paragraphs A3.5 and A3.6, the stage-frequency curves for improved conditions were developed.

A3.8 Flooded Areas by Reach, Existing and Improved Conditions

Table A3.2 presents a tabulation of flooded areas for the 500, 200, 100, 50, 20, 10, and 2-year floods under existing and improved conditions. Stage-area curves from the Tonawnada Creek Watershed Agricultural Activity Study (12) were utilized along with the appropriate stage-frequency curves to construct Table A3.2.

A4. UPPER TONAWANDA CREEK WATERSHED - HOPKINS ROAD TO ATTICA, NY

A4.1 General

This subsection describes the results of hydrologic investigations for the watershed area from Hopkins Road (mile 41.5) upstream to Attica, NY. For purposes of determining average annual damages, the area was divided into 11 damage reaches, T-11, T-12, B-1 through B-5, T-13, and A-1 through A-3. A detailed damage reach description is included in Appendix B. These reaches are shown on Plates A1b and A1c.

A4.2 Stage-Discharge Curves, Existing Conditions

A stage-discharge curve for the USGS gaging station located within the limits of Reach B-2 in Batavia is shown on Plate A113. This curve was developed from discharge measurements made by the USGS and is fairly well defined for flows up to 6,900 cfs with further extrapolation accomplished by this office. This station has been rerated since completion of the Corps of Engineers local protection project in 1955.

A4.3 Stage-discharge curves were developed for each reach except T-11. A curve for T-11 could not be developed due to the lack of cross sectional data. Reach T-11 was addressed by other methods described in subsequent paragraphs. The rating curve for index point T-12 was developed by means of a conveyance curve and high water marks from several previous floods. The conveyance curve was then adjusted slightly by discharge measurements made at known flows, correlated with the gage at Batavia. The rating curves for the remainder of the damage reaches were calculated by backwater computations using Method I as described in EM 1110-2-1409, dated 7 December 1959 and titled "Backwater Curves in River Channels." Reaches B-2 and B-3 have a common index point in Kibbe Park and the rating curve developed at this point was used for both reaches. Reaches B-4 and B-5 also have a common index point at the Chestnut Street bridge and the rating curve developed for this point was used for both reaches. The rating curves for Reaches T-12, B-1 through B-5, T-13, and A-1 through A-3 are shown on Plates A114 through A121.

A4.4 Discharge-Frequency Curves, Existing Conditions

The existing discharge-frequency curve for the Batavia Gage is shown on Plate A15. This curve is applicable to Reaches T-11, T-12, and B-1 thru B-5. It is reproduced on Plate A122 for comparison with the improved discharge-frequency curve. The discharge-frequency curves labeled "Tonawanda Creek at Alexander" and "Tonawanda Creek at Attica" on Plate A16 are applicable to reach A-1 and Reaches A-2 and A-3, respectively. These curves were developed using the procedures discussed i ection A1.

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onawanda reek Watershed Agricultural Activity Study Supplemental Report, AFCRA Research, Inc., WENDEL Engineers, P.C., 1978.

A4.5 Discharge-Frequency Curves, Improved Conditions

The improved discharge-frequency curves applicable to Reaches T-11, T-12, and B-1 through B-5 are shown on Plate A122. They were developed by operating the recommended structures for balanced hydrographs with various return periods and then plotting the resulting peak outflow versus the return period of the balanced hydrograph. The recommended improvements are downstream from Reaches A-1 through A-3, therefore, the improved discharge-frequency curves for these reaches will be the same as the existing curves.

A4.6 Stage-Frequency Curves, Existing Conditions

For determining existing average annual damages, stage-frequency curves were developed for the index points. The curve for Reach T-11 was developed using the method described in paragraphs A3.5 and A3.6 with the existing conditions discharge-frequency curve for the Batavia Gage as the basis. The curves for Reaches T-12, B-1 through B-5, and A-1 through A-3 were developed from the existing conditions stage-discharge curves for the respective index points and the existing conditions discharge-frequency curves discussed in paragraph A4.4. The curve for Reach T-13 was developed from routing balanced hydrographs through the natural stream system and plotting the resulting stage versus the frequency of the balanced hydrograph. Existing conditions stage-frequency curves for Reaches T-11, T-12, B-1 through B-5, T-13, and A-1 through A-3 are shown on Plates A123 through A131.

A4.7 Stage-Frequency Curves, Improved Conditions

Stage-frequency curves for improved conditions were developed for the index points for the recommended plan and are shown on Plates A122 through A131, along with the curves for existing conditions. The curves for Reach T-11 were developed using the method described in paragraphs A3.5 and A3.6 with the improved conditions discharge-frequency curves at the Batavia Gage as the basis. The curves for Reaches T-12 and B-1 through B-5 were developed from the existing conditions stage-discharge curves for the respective index points and the improved conditions discharge-frequency curves for the Batavia Gage. The curves for Reach T-13 were determined from operating the considered structures for balanced hydrographs with various return periods and plotting the resultant pool level versus the return period of the balanced hydrograph. Curves for Reaches A-1 through A-3 were not developed as the considered structures are located downstream from these reaches and would, therefore, not affect the stage-frequency relationship at these index points. These improved stage-frequency curves in conjunction with the appropriate stage-damage were used to determine residual average annual damages and benefits.

A4.8 Flooded Areas by Reach, Existing and Improved Conditions

Table A3.2 presents a tabulation of flooded areas for the 500, 200, 100, 50, 20, 10, and 2-year floods under existing and improved conditions.

A5. HYDRAULIC DESIGN

A5.1 General

The Batavia Reservoir Compound, located south of the city of Batavia, was considered as part of the flood management measures for Tonawanda Creek watershed. Batavia Reservoir Compound includes an upper impoundment located near the Erie-Lackawanna Railroad embankment and a lower impoundment located approximately one-half mile upstream from the Lehigh Valley Railroad embankment. Hydraulic structures designed consist of earthen dams and dikes, concrete culverts, sluice gates, stilling basins, a diversion channel, and spillways. The locations of these structures are shown on Plate B5 (Batavia Reservoir Compound). Hydraulic design of the structures is based on the information presented in the references: (i) Hydraulic Design of Stilling Basins and Energy Dissipators by A.J. Peterka, Engineering Monograph No. 25, U.S. Department of the Interior, Bureau of Reclamation, July 1963; (ii) Spillway for Typical Low-Head Navigation Dam, Arkansas River, by J.L. Grace, Technical Report No. 2-655, U.S. Army Engineer Waterways Experiment Station, September 1964; and (iii) Open Channel Hydraulics by Ven Te Chow, McGraw-Hill Book Company, 1959. During Advanced Engineering and Design the actual freeboard needed for nonoverflow portions will be determined based upon guidance contained in Civil Works Engineering Bulletin 54-14 and other appropriate guidance.

A5.2 Batavia Reservoir Compound, Upper Reservoir

The principal structure includes an earth embankment, a concrete culvert, and a stilling basin. Details of the culvert and stilling basin designs are shown on Table A5.1. Flow through the culvert would be controlled by five sluice gates each 11 feet wide and 11 feet high. The culvert is designed to pass the discharge of 2,000 cfs at a low stage of 906.2. The culvert has the capacity of 10,700 cfs, at a high stage of 922.5. Flow would overtop the spillway for floods with an average return period greater than 100 years. The embankment, having a length of about 5,600 feet, would be used in combination with the gates to pass the Standard Project Flood of 38,600 cfs at a stage of 924.5. The discharge capacity of the overflow spillway was designed using the weirflow equation with a "C" coefficient ranging between 2.5 and 1.6 depending on the tailwater conditions. For the design overflow discharge of 27,900 cfs, a weir coefficient of 1.76 was used when the upper pool level is at 924.5 feet and the tailwater level is at 915.0 feet. The downstream face of the embankment would be riprapped to withstand a sheet flow having a maximum velocity of about 8 feet per second. The stilling basin and the shape for placement of riprap are designed from the information presented in the references (ii) and (iii) listed in paragraph A5.1.

A5.3 Batavia Reservoir Compound, Lower Reservoir

The principal structure includes an earth embankment with a rectangular concrete culvert similar to the culvert designed for the Upper Reservoir and a stilling basin. Flow through the culvert would be controlled by four sluice gates 11 feet wide and 11 feet high. The culvert is designed to pass a discharge of 6,000 cfs at a stage of 900.0 which is 6.2 feet above the

Table A5.1 - Hydraulic Design Data

Description	Batavia Reservoir Compound: Upper Reservoir	Batavia Reservoir Compound: Lower Reservoir
Standard Project Flood Discharges - cfs		
Inflow	38,800	50,200
Outflow	38,600	28,400
Controlled	2,000	6,000
Max. through culvert	10,700	6,000
Overflow	27,900	22,400
Elevations (USC&GS Datum) and Storages		
Top of Embankment - feet	922.5	905.5
Maximum Pool		
Headwater Elevation - feet	924.5	902.5
Tailwater Elevation - feet	915.0	902.0
Storage - inches	1.6	2.5
Flood Control		
Headwater Elevation - feet	922.5	900.0
Tailwater Elevation - feet	910.9	893.9
Storage - inches	1.2	1.7
Channel Bottom Elevation near the dam - feet	900.0	880.0
Maximum Velocities - ft./sec.		
Culvert Outlets	22.0	16.0
Spillway	8.0	4.0
Culvert and Sluice Gate		
Invert elevation (feet) at:		
Inlet	900.0	880.0
Outlet	900.0	879.0
Height - feet	11.0	11.0
Width - feet	11.0	11.0
Number	5 1/	4 1/
Stilling Basin:		
Type	concrete	concrete
End Sill	Yes	Yes
Baffle Blocks	Yes	Yes
Overflow Section:		
Type	paved	paved
Crest elevation - feet	922.5	900.0
Length - feet	5,600	4,000
Contributing Drainage Area - sq. mi.	102	171
Channel Capacity Downstream from Dam - cfs	2,000	6,000

1/ Includes one spare gate

tailwater. Velocities of about 16 feet per second would exist near the culvert inlet and outlet areas where a stilling basin would be provided. The embankment functions as an overflow spillway with a crest elevation of 900 feet and overflow length of 4,000 feet. Flow would overtop the emergency spillway for floods with an average return period greater than 500 years. For the design overflow discharge of 22,400 cfs, a weir flow coefficient of 1.64 was used when the upper pool level is at 902.5 and the tailwater level is at 902.0 feet. The hydraulic design data for the principal structure and overflow spillway are given in Table A5.1.

A6. RESPONSE TO COMMENTS IN THE MEMORANDUM FOR RECORD, 9 FEBRUARY 1977

Below are responses to comments in the Memorandum for Record, NCDPD-PF, 9 February 1977 which are applicable to this appendix.

1. Route the Probable Maximum Flood (PMF) through the recommended plan. Discuss impacts.

As discussed in paragraph A1.61, the Probable Maximum Storm was centered over the Tonawanda Creek watershed above Alexander in order to maximize the peak discharge at Alexander and Batavia. This insured the PMF discharges at the Upper and Lower Reservoir were the highest possible to test the performance of the spillways. Table A1.20 presents the PMF discharges and elevations.

The HEC-5C hydrograph routings indicated that the outflow from the Lower Reservoir will be the same for existing and improved conditions. This indicates that the spillway discharge will not significantly increase the hazardous condition downstream from the spillway. Hence, in accordance with ER 1110-2-1451, no real estate interest will be required in the city of Batavia.

2. Show impact of upper dam failure.

In paragaphs A2.39 and A2.40 it is indicated that during Advanced Engineering and Design, the dam failure analyses along with flooded area maps will be completed in accordance with ER 1130-2-419, "Project Operation, Dam Operations Management Program," using a sophisticated unsteady flow model. For the purpose of this report a dam failure analysis was completed using "Flood Hydrograph Package HEC-1 for Dam Safety Investigations." Paragraphs A2.41 through A2.44 discuss the impact of the Upper Dam failure with the hydrographs shown on Plates A54a and A57a.

The field surveys taken in the Lower Reservoir area in Winter 1977-1978, coupled with a cursory hydraulic analysis, indicated that the previous (1976 report) location of the emergency spillway was impossible. Instead, under the latest plan, the Lower Reservoir embankment would function as an emergency spillway at elevation 900 feet. Lateral (training) dikes will prevent the diversion of discharge around Batavia.

8. Show frequency curves which represent the split in flows through and around Batavia. Show that the damages and benefits were derived from the split frequency curves.

Comment no longer applicable. See No. 4 above.

9. Define the route of the diverted water.

Comment no longer applicable. See No. 4 above.

10. Hydrographs showing natural and modified conditions should be shown.

Balanced hydrographs for the 200, 50, and 2-year floods are shown on Plates A42 through A58. Inflow/outflow discharge and stage hydrographs for the reservoir along with hydrographs for the confluence with Ledge Creek for existing and modified conditions are shown. Hydrographs for the March 1960, March 1978, and September 1977 are shown on Plates A59 through A71. SPF and PMF hydrographs are shown on Plates A72 through A80.

11. Table A-26, add a column to show the effect of the Upper Reservoir by itself.

The table referenced is nonexistent; however, it was assumed that the comment was addressing Table A2.2 of the 1976 report. Balanced floods and the March 1978 flood were routed through the entire Tonawanda stream network assuming the Upper Reservoir alone in place. Results of these routings may be found in Tables A1.7 through A1.13 and Table A1.16. Tables A2.3 through A2.6 present the effect of the Upper Reservoir only on the balanced and March 1978 flood in the Lower Reservoir area.

14. Provide additional backup for channel capacities.

Channel capacities for Tonawanda Creek are discussed in paragraphs A1.8 through A1.13. Since backwater calculations were not performed, it was necessary to infer a range of channel capacity for a reach from a study of the stream gage records and field observations. Table A1.3c presents ranges of channel capacities for Tonawanda Creek reaches. The more conservative estimates were used in operation studies in order not to overstate the benefits.

15. Perform a sensitivity analysis to assess the effect of improved mapping of the project.

During the Winter of 1977, Buffalo District personnel completed field surveys in the Lower Reservoir area of the proposed Batavia Reservoir Compound. Part of the information received led to the conclusion that the location of the emergency spillway, as delineated in the 1976 report, was hydraulically impossible. This finding points out the importance of sufficient topographical detail when proposing a project.

16. Evaluate the significance the local area inflows downstream of the project will have on the improved stage-frequency curves at Alabama.

Balanced hydrographs were routed and combined with local area inflow for the Tonawanda Creek watershed from Alexander, NY, to the confluence with Ransom Creek. Existing and improved conditions were investigated. The stage-frequency curves at Alabama are shown on Plate A98.

17. Revise, statistically, the frequency curves without regard to the Standard Project Flood. The frequency curves do not have to conform to the Water Resources Council Bulletin 17 guidelines. Use the new frequency curves in the benefit analysis.

The results of the regional frequency analysis completed for this study were used in the calculation of the balanced hydrographs. The 500, 200, 100, 50, 20, 10, and 2-year hydrographs were routed and combined at selected index points along Tonawanda Creek. This information was used in the calculation of the frequency curves and utilized in the benefit analysis.

18. Assess any adverse effect of increased duration of release on the downstream area.

In many cases when a release is maintained for a considerable period of time, even if within channel capacity, the groundwater table may increase. Low areas which may be one-half mile or more from the channel can begin to fill up or become so swampy that it will not support farm equipment. Study funding constraints precluded the possibility of performing groundwater and backwater studies. Table A2.3 shows that under project conditions, overbank flooding in the Rapids, NY, area will persist for approximately 1 day longer than what whould have existed under natural conditions. Flows would be near to or exceeding channel capacity for only a few days longer than existing flooding. This would not be detrimental to drainage of farmland during late fall to early spring months. During months of agricultural activity certain crops may be affected.

19. Discuss sediment storage and the affect it would have on project formulation.

One of the most obvious consequences of sediment deposits is the depletion of reservoir storage capacity. Since the reservoirs will normally be dry and the gates fully open, it is felt that the sediment characteristics of Tonawanda Creek will not be greatly affected.

20. Show the effect the project has on a flood of record.

Beginning as inflow to the Lower Reservoir, the March-April 1960 flood was routed and combined with local area inflow along Tonawanda Creek to Rapids, NY, as described in paragraphs A1.44 and A2.29. Table A1.14 presents the peak discharge at various index points for existing and improved conditions. Tables A2.5 and A2.26 show the effect of the Lower Reservoir on the 1960 flood. The hydrographs are presented on Plates A59-A62.

24. Explain why modified and natural discharge profiles for various frequency floods such as the 10, 100, and 200-year floods cannot be constructed.

The Buffalo District requested funding to perform backwater computations and to obtain aerial surveys. This request was denied by higher headquarters. Modified and natural profiles cannot be developed without backwater computations.

28. Develop a hydrograph for Ledge Creek near confluences with Tonawanda Creek for the 1960 flood.

Paragraph A1.38 describes the development of the 1960 flood for Tonawanda Creek below the confluence with Ledge Creek with existing and improved hydrographs shown on Plate A61. This was essential in the determination of cumulative local area runoff between the Lower Reservoir to just downstream of the confluence with Ledge Creek. That area was used in the determination of releases from the Lower Reservoir.

A7. RESPONSE TO COMMENTS IN THE MEMORANDUM OF UNDERSTANDING, 39 JUNE 1980

Below are the responses to comments and portions thereof from the Memorandum of Understanding, NCDPD-PF, 30 June 1980, which are applicable to this appendix. The Memorandum of Understanding, 30 June 1980, replaces the MOU sent with NCD 1st Indorsement, 24 April 1980.

Engineering Division - Water Control Center Comments:

2. The report must show the impact of the project on the area flooded downstream by showing the flood (10-year) and the SPF. Plate 14 does not show adequate detail in presenting the flooded area. The map which shows the flooded areas must show streets and individual houses in the town of Batavia.

The 30 June 1980 MOU indicates that flooded area maps should be constructed delineating the flooded outline for a historic flood (March 1960) for with and without project conditions. On the maps, arrows will be drawn showing the path of the water and range of channel capacity in the reach. A tabulation of the flooded area for existing and improved conditions for the balanced hydrograph routings will be made. Flooded area maps for the 100-year and SPF should be constructed in the city of Batavia for with and without project conditions.

Plates A2a through A2c present the flooded outline for existing and improved conditions for the March 1960 flood with arrows showing the path of the water Table A3.2 presents a tabulation of the flooded areas for existing and improved conditions for the balanced hydrograph routings. Utilizing limited flood evaluation and topographic information, the approximate 100-year and Standard Project flood outlines in the city of Batavia for with and without project conditions are presented on Plate A1d.

5. Revise Table A5.1 to show storage in inches, drainage areas and channel capacities for both reservoirs.

Table A5.1 has been revised.

7. Page A-64, comment No. 1 - Uncertainty in the rating curve for the lower reservoir is not a basis for concluding that the spillway discharge would not significantly increase the hazard condition from the spillway. This is reinforced by the statement that the project would increase the design discharge. The effect of the project increases the design flow, additional area inundated by the higher flow during a SPF event should be delineated and the additional area effected should be purchased.

The effect of the project on the SPF discharges has been reevaluated. Originally a 3-hour time interval was used during the routing and combining of the SPF. This proved to be insufficient near the peak of the hydrograph. To improve the accuracy of the peak discharge a 1-hour time interval was used near the peak. Table A7.1 presents a comparison of the previous SPF peak discharges and the present discharges derived using a 1-hour interval.

As can be seen in Table A7.1, the SPF peak discharge is reduced for with project conditions and hence in accordance with ER 1110-2-1451, no real estate interest will be required in the city of Batavia.

Table A7.1 - SPF Peak Discharges, 1979 and 1980 Analysis

	Existing		Improved	
	1979	1980	1979	1980
Alexander				
(Upper Reservoir)				
Inflow	38,800 cfs	38,800 cfs	38,800 cfs	38,800 cfs
Outflow	40,000 cfs	38,500 cfs	39,000 cfs	38,600 cfs
Elevation	923.8 feet	923.8 feet	924.5 feet	924.5 feet
Batavia				
(Lower Reservoir)				
Inflow	52,100 cfs	49,200 cfs	53,000 cfs	50,200 cfs
Outflow	28,100 cfs	28,500 cfs	29,400 cfs	28,400 cfs
Elevation	901.9 feet	902.0 feet	902.6 feet	902.5 feet

8. Because of the proximity of the project to the city of Batavia, the report must describe (in at least a preliminary manner), the manner and effects of failure of the Lower Dam. Include discussion of the method of riprapping and possible concrete lip.

In paragraphs A2.39 and A2.40 it is indicated that during Advanced Engineering and Design the dam failure analysis along with flood area maps will be completed in accordance with ER 1130-2-419, "Project Operation, Dam Operations Management Program," using a sophisticated unsteady flow model. For the purpose of this report a dam failure analysis was completed using "Flood Hydrograph Package HEC-1 for Dam Safety Investigations." Paragraphs A2.45 and A2.46 discuss the impact of the Lower Dam failure with the hydrographs shown on Plate A57b.

9. Page A-65 - The response of comment 14 regarding the determination of downstream channel capacities is not adequate. The determination of accurate channel capacities is an extremely important item in the evaluation of reservoir performance. The sections should be obtained and backwater runs should be completed for all reaches where small changes in the stage have a large impact on damages and resulting benefits. This is a very important item in that an underestimate of downstream channel capacities can have a dramatic effect on the formulation and operation of the project. The report should describe the effects that a reasonable range of channel capacity would have on the operation and economics of the project.

It is agreed that the discussion of channel capacities was not adequate. Paragraphs A1.8 through A1.14 present a discussion of channel capacities and their determination using rating curves at USGS gaging stations coupled with field observations. Table A1.3c presents ranges of channel capacities for Tonawanda Creek reaches.

10. The operation of the reservoir for floods larger than a 10-year event assumes that it is known that such a large flood is in progress. In the actual operation of the project, the regulation personnel would not have this advanced knowledge. There should be a consistent operation policy for all floods. In order to make the operation practical, the gate settings should be determined as a function of reservoir stage and local (downstream) flows and not only a function of the inflow into the project. This operating plan should apply to <u>all</u> floods and should not be limited to floods of a specific frequency.

As indicated in the Memorandum of Understanding between North Central Division and Buffalo District, 30 June 1980, the operation plan for the reservoirs will remain as a function of inflow and downstream flows with a two-scheme operation dependent upon the severity (frequency) of the flood. In paragraphs A2.14 and A2.15, discussion concerning this matter is presented.

11. Tables A-1. and A-1.8 - A1.12, plus A-15 should be used to construct discharge-frequency curves for existing and modified conditions at several locations downstream from the project.

As explained in paragraph A2.33, Table A1.7 through A1.16 were used to construct frequency curves at several locations downstream of the project. It should be noted that the frequency curves at Rapids and the confluence to Mud Creek with Tonawanda Creek include the diversion discharges.

12. The impact of increased local inflow, due to reductions in stage on Tonawanda Creek and resultant decrease in backwater effect on the tributaries, should be evaluated.

The local inflow hydrographs developed for existing conditions were used in the routing calculations for improved conditions, as the decrease in backwater effect on the tributaries will be minimal. Further explanation is given in paragraph A2.1.

13. Discussion in report should be modified. The impact of a reservoir on downstream discharge usually decreases in a downstream direction, both in percentage and net reduction. The tables showing the routings of the balanced hydrographs show that the net effect of the project remains the same and even increases in some cases. This tendancy is questioned especially when it is considered that the impact of Comment 19 is to decrease the effect fo the project with respect to distance downstream of the project.

As can be seen in Table A2.7, the impact of the reservoirs on the downstream discharges decreases in a downstream direction both in percentage and net reduction. For further discussion refer to paragraph A2.33.

14. Pages A-18 to 24 - The balanced hydrograph routings should show the inches of runoff stored for with project conditions.

Footnotes have been added to Tables A1.7 through A1.13 and present the quantity of water stored in the Upper Reservoir alone and the Batavia Reservoir Compound for all frequencies.

15. Routings of the historic storms show that the effect of the proposed project decreases downstream. This tendency appears inconsistent with the results of the balanced hydrographs. This point should be discussed in the report.

This comment is similar to comment 13 and is explained in paragraph A2.33. As shown in Table A2.7, the peak discharge reduction at Batavia would be 47 percent for the recurrence of the March 1978 flood, but only 25 percent at Rapids.

16. Page A-33 - Review of EC 1110-2-163 indicates that safety standard 3 is not appropriate for design of the Tonawanda Project. Standard 3 is appropriate only for emergency spillage which may operate in lieu of service spillways. Since the project does not have a service spillway, this standard does not appear appropriate. It appears that standard 2 is more appropriate. This calls for adequate outlet capacity to be available to limit head differences at time of overtopping to reduce risks downstream in the event of breaking.

The Buffalo District maintains the conviction that Standard 3 is the appropriate safety standard for the reservoirs. Comment 16 indicates that Standard 3 is appropriate only for emergency spillage which may operate in lieu of service spillways. This interpretation seems to be in error as EC 1110-2-163 uses that only as a possible example for the application of Standard 3 and not necessarily as a requirement. Comment 16 also indicates that the project does not have a service spillway. It should be clarified that the Upper and Lower Dam of the Batavia Reservoir Compound have "limited service" spillways as they are used infrequently for the operation of the reservoirs and do not incur excessive damage to the spillway structure by erosion or to downstream areas from deposition of eroded material.

Due to the limited fetch, wind-induced wave action will not be a significant factor in determination of the top elevation of the dam. Further discussion may be found in paragraph A1.53 through A1.57 on the selection of the safety standard. It is suggested that during Advanced Engineering and Design the application of the appropriate safety standard be studied further and assistance from the Board of Engineers and OCE be solicited if a disagreement remains.

17. Plate A-74 and A-80 - The report shows that the outflow from the project is increased for both the SPF and PMF. The basis for this increase in flow should be explained.

As shown presently on Plates A-74 and A-80, the outflow from the project is not increased for both the SPF and PMF. As indicated in response to comment 7 and in paragraph A1.50, a refined routing was done near the peak which resulted in more accurate and credible discharges.

18. The report should discuss the sizing of the outlet works and the overflow embankment. The present report gives no basis for the sizing of the components. The outlet works must be able to pass the flow required to minimize the stage at the time of overtopping.

In Section A5 a discussion on the sizing of the outlet works is presented. Component sizes are tabulated in Table A5.1.

19. The report should discuss the protection to be used on the overflow embankments including design flow, design velocity and design TW evaluation for both the upper and lower dams.

This discussion may be found in Section A5 and presented in Table A5.1.

20. The report should present more legible plates which show the downstream damages reaches. The report should present flow distribution charts for a large magnitude flood for the flows which enter the downstream tributaries.

On Plate A2a through A2e the Tonawanda Creek reaches are presented along with the flow distributions for the March 1960 flood.

21. Usually hydrologic models are constructed from sub-area unit hydrographs and the resulting flood hydrographs for historic events are compared to historic flood hydrograph data as a check of the model performance regarding timing, volume, and flood magnitude reproduction. The synthetic events in turn are usually checked at locations of gaging records against the independent statistical results of peak flows and volumes. During this process the model loss rates are usually maintained somewhat consistent down through the watershed. This results in the effect that each sub-area will produce a reasonable contribution of runoff compared to the other sub-areas. Since for the Tonawanda study both the analysis for historic events and synthetic events uses results of the gage data directly in their derivation, the above consistency checks are more difficult. The creation of a hydrologic model consisting of sub-area components which match a series of balanced hydrographs throughout an entire watershed is very difficult to create. With respect to Tables A1.7 through A1.13, are the relative contributions of each sub-area reasonably consistent with regard to peaks and volumes?

It is agreed that hydrologic models are often constructed from subarea unit hydrographs and the resulting flood hydrographs for historic events are compared to historic flood hydrograph data as a check of the model performance. However, the balanced hydrograph method was in this case the most appropriate and implementable technique. The upstream balanced hydrographs were routed and subtracted from downstream balanced hydrographs to calculate the local area inflow hydrographs. Necessary minor adjustments were made to insure consistent relative contributions of each subarea with respect to peaks and volumes. If sufficient data had been available a period of record routing would have been the most informative. Further discussion concerning the rationale for selection of the balanced hydrograph approach may be found in paragraph A1.24.

AD-A101 439 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2
BUFFALO METROPOLITAN AREA, NEW YORK WATER RESOURCES MANAGEMENT --ETC(U)
1980

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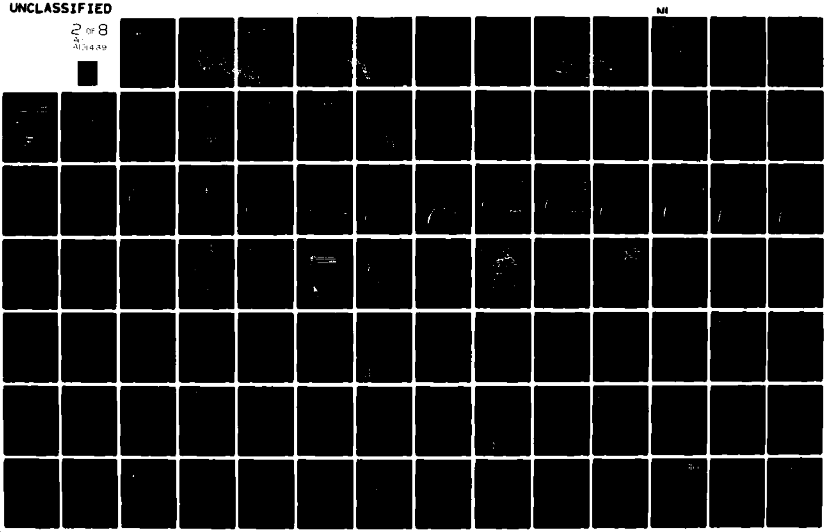
2 OF 8
AD
A101439



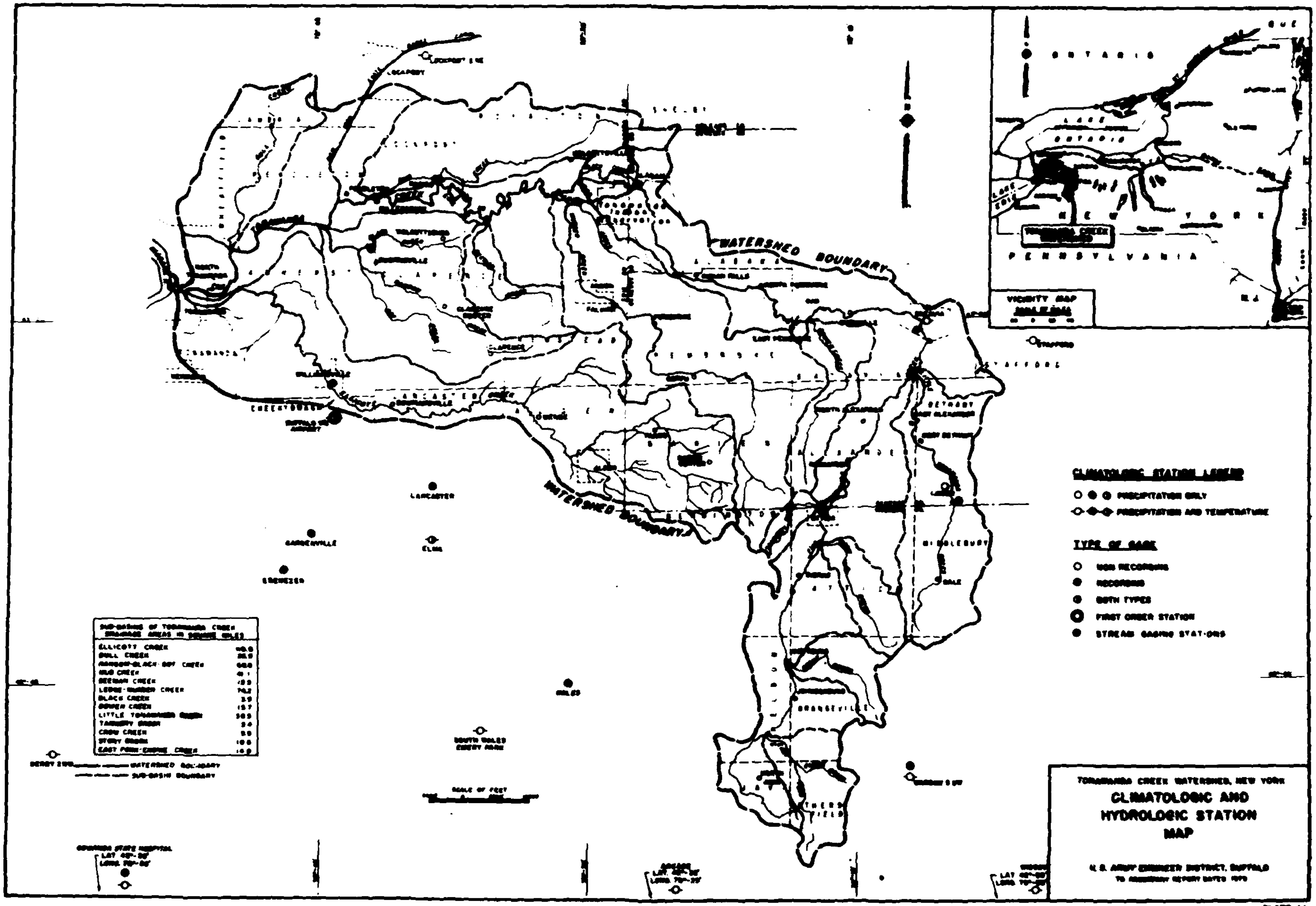
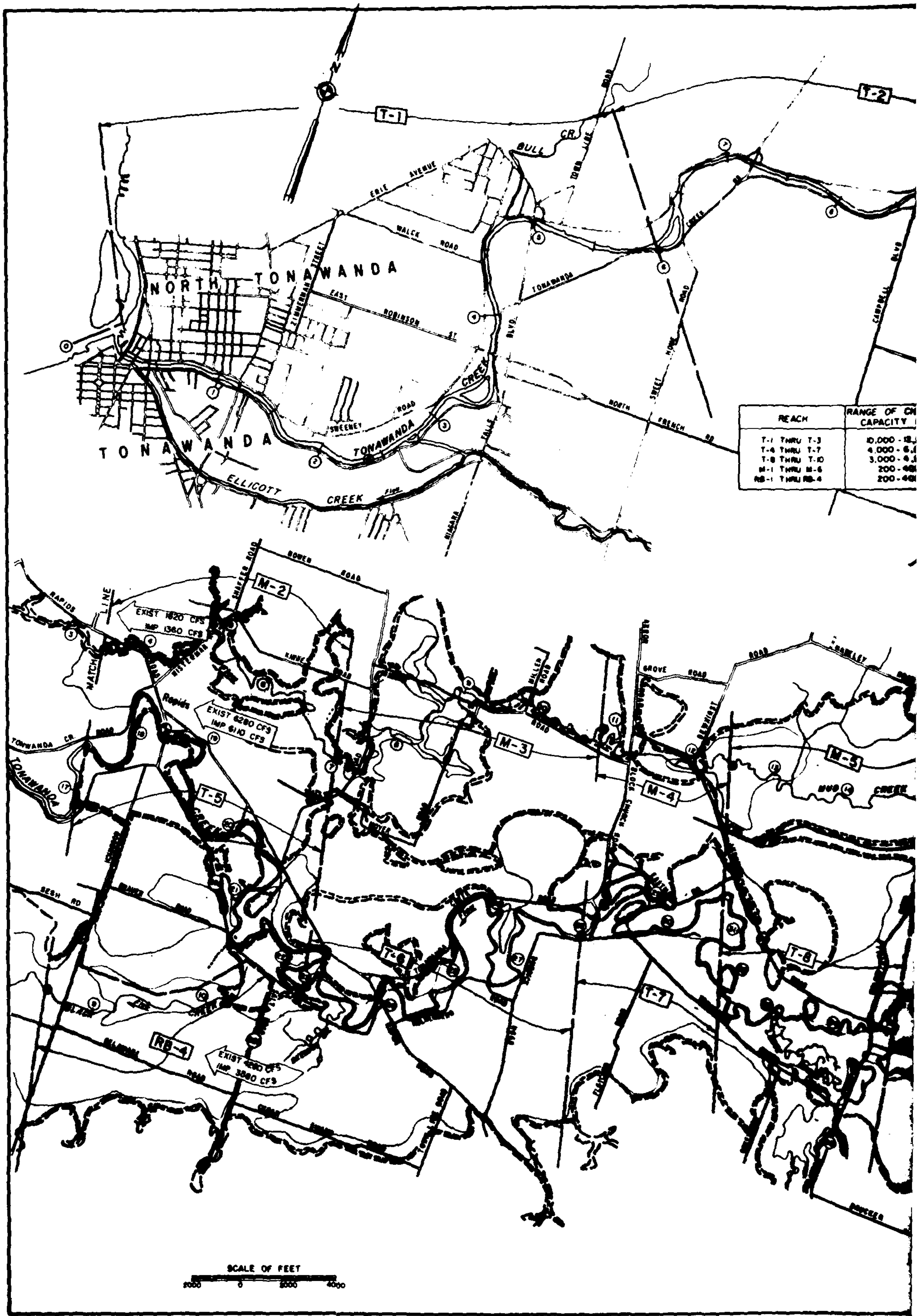
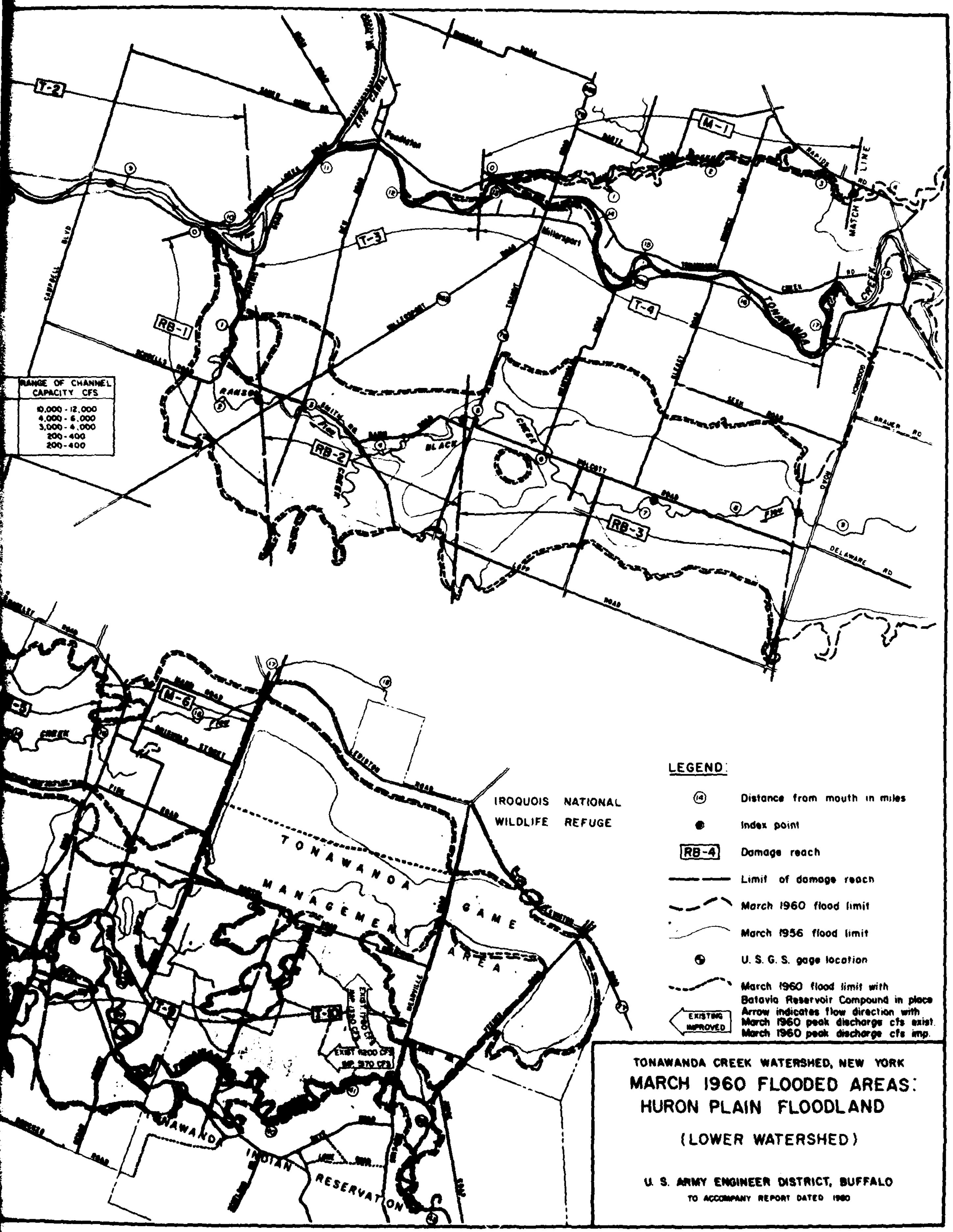

WATERSHED BOUNDARY
ONTARIO
NEW YORK
PENNSYLVANIA
VICINITY MAP
CLIMATOLOGIC STATION LEGEND
PRECIPITATION ONLY
PRECIPITATION AND TEMPERATURE
TYPE OF GAGE
NON RECORDING
RECORDING
BOTH TYPES
FIRST ORDER STATION
STREAM GAGING STATIONS
LANCASTER
GARDENVILLE
ELMA
SUB-BASIN BOUNDARY
TONAWANDA CREEK WATERSHED, NEW YORK
CLIMATOLOGIC AND
HYDROLOGIC STATION
MAP
U. S. ARMY ENGINEER DISTRICT, BUFFALO

PLATE A1

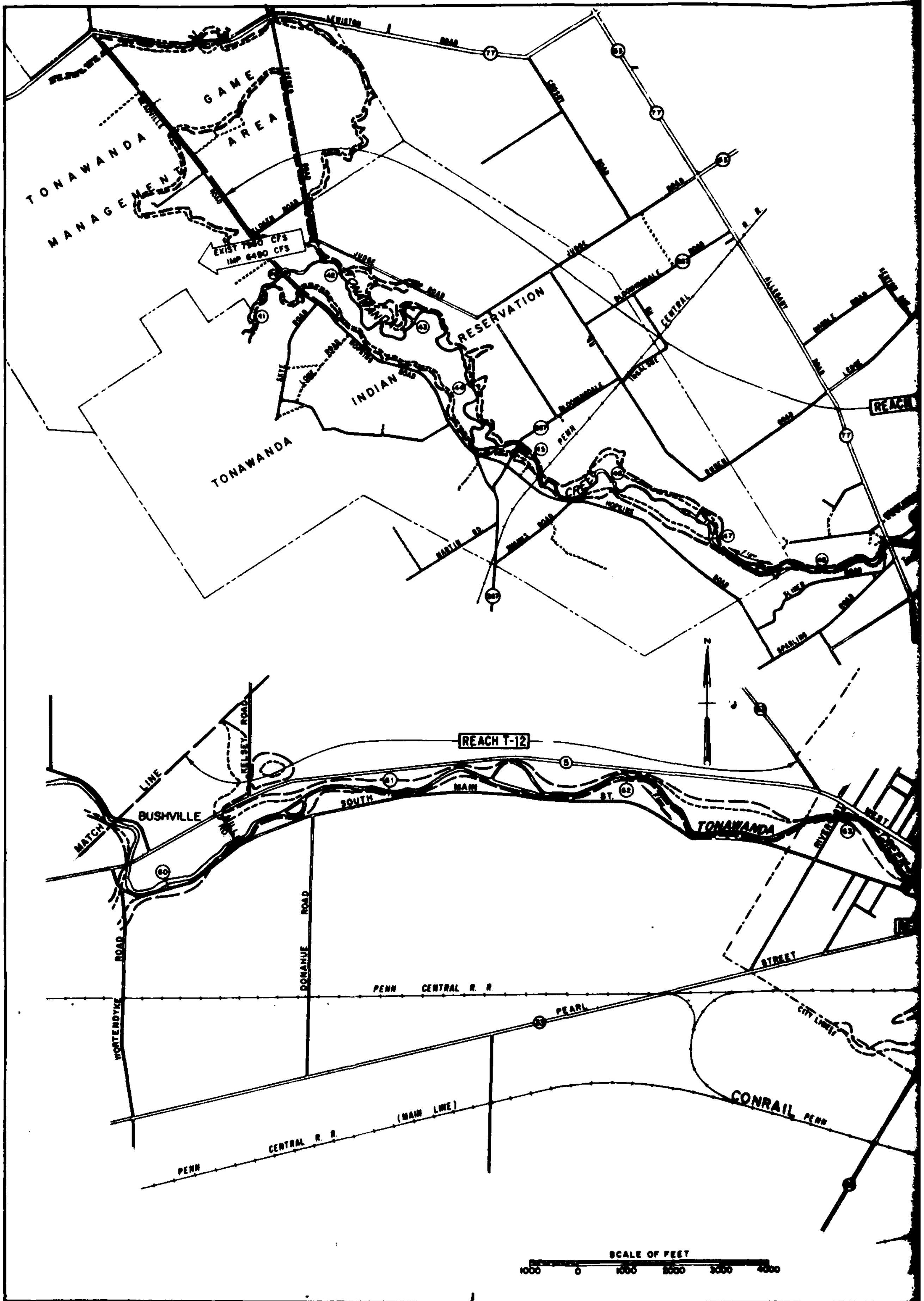


NORTH TONAWANDA
TONAWANDA
T-1
T-2
BULL CR
ERIE AVENUE
WALCK ROAD
EAST ROBINSON ST
SWEENEY ROAD
TONAWANDA CREEK
ELLICOTT CREEK
NORTH FRENCH RD
CAMPBELL BLVD
REACH
RANGE OF CH
CAPACITY
T-1 THRU T-3
T-4 THRU T-7
T-8 THRU T-10
M-1 THRU M-6
RB-1 THRU RB-4
M-2
BOWEN ROAD
RAPIDS
EXIST 1620 CFS
IMP 1360 CFS
EXIST 6280 CFS
IMP 6110 CFS
TONAWANDA CR. ROAD
M-3
M-4
M-5
GROVE ROAD
T-5
T-6
T-7
T-8
RB-4
EXIST 4260 CFS
IMP 3560 CFS
SCALE OF FEET
2000 0 2000 4000

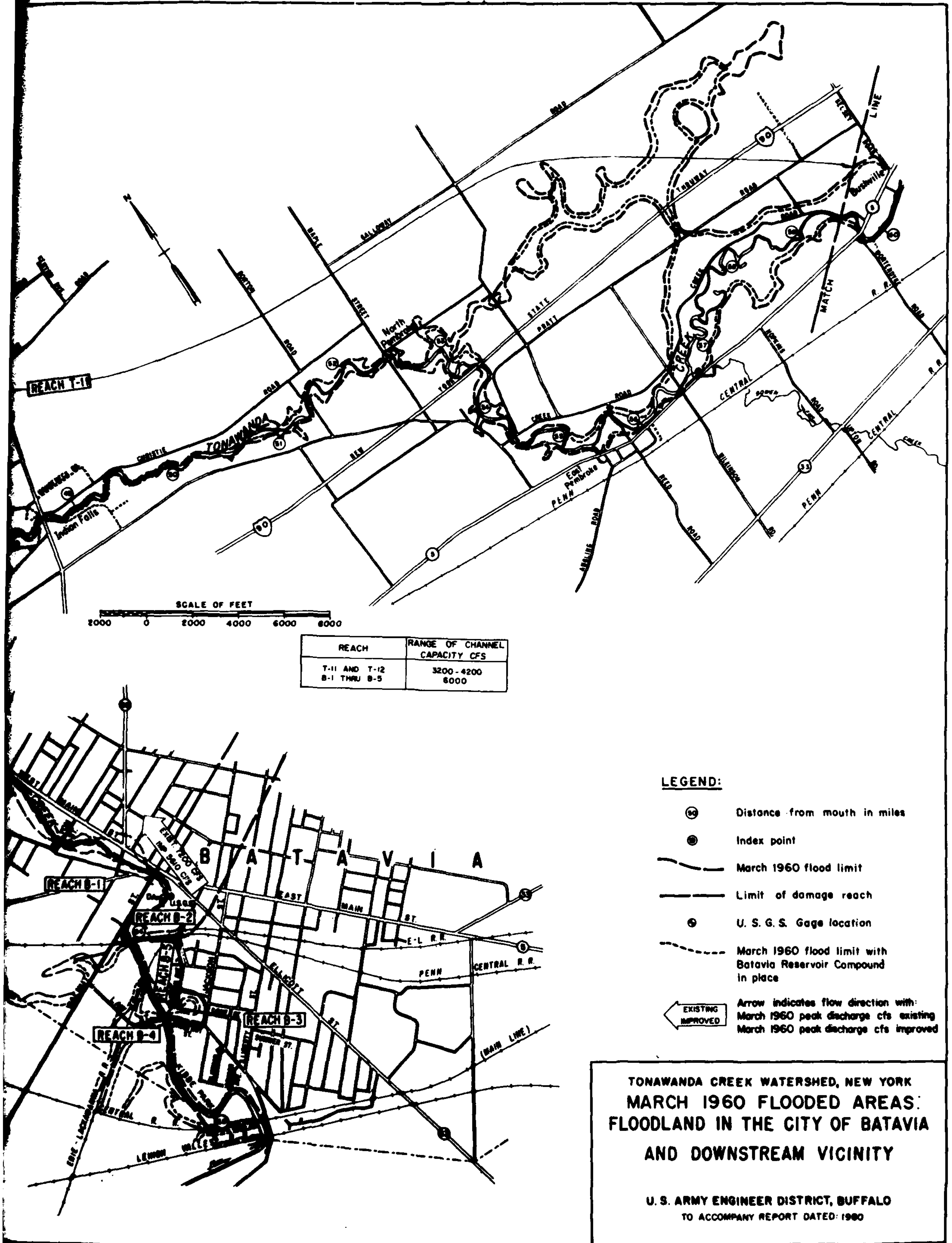


TONAWANDA CREEK WATERSHED, NEW YORK
MARCH 1960 FLOODED AREAS:
HURON PLAIN FLOODLAND
(LOWER WATERSHED)
U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED 1960
LEGEND:
Distance from mouth in miles
Index point
RB-4 Damage reach
Limit of damage reach
March 1960 flood limit
March 1956 flood limit
U. S. G. S. gage location
March 1960 flood limit with Batavia Reservoir Compound in place
Arrow indicates flow direction with March 1960 peak discharge cfs exist. March 1960 peak discharge cfs imp.
EXISTING IMPROVED
RANGE OF CHANNEL CAPACITY CFS
10,000 - 12,000
4,000 - 6,000
3,000 - 4,000
200 - 400
200 - 400
T-2
T-3
T-4
M-1
M-6
RB-1
RB-2
RB-3
T-9
T-10
MATCH LINE
IROQUOIS NATIONAL WILDLIFE REFUGE
TONAWANDA GAME MANAGEMENT AREA
TONAWANDA INDIAN RESERVATION
TONAWANDA CREEK
BLACK CREEK
ERIE CANAL
CAMPBELL BLVD
DELAWARE RD
BRAUER RD
LEWISTON ROAD
Pendleton
Millersport
EXIST 11200 CFS
IMP 11570 CFS

PLATE A-10

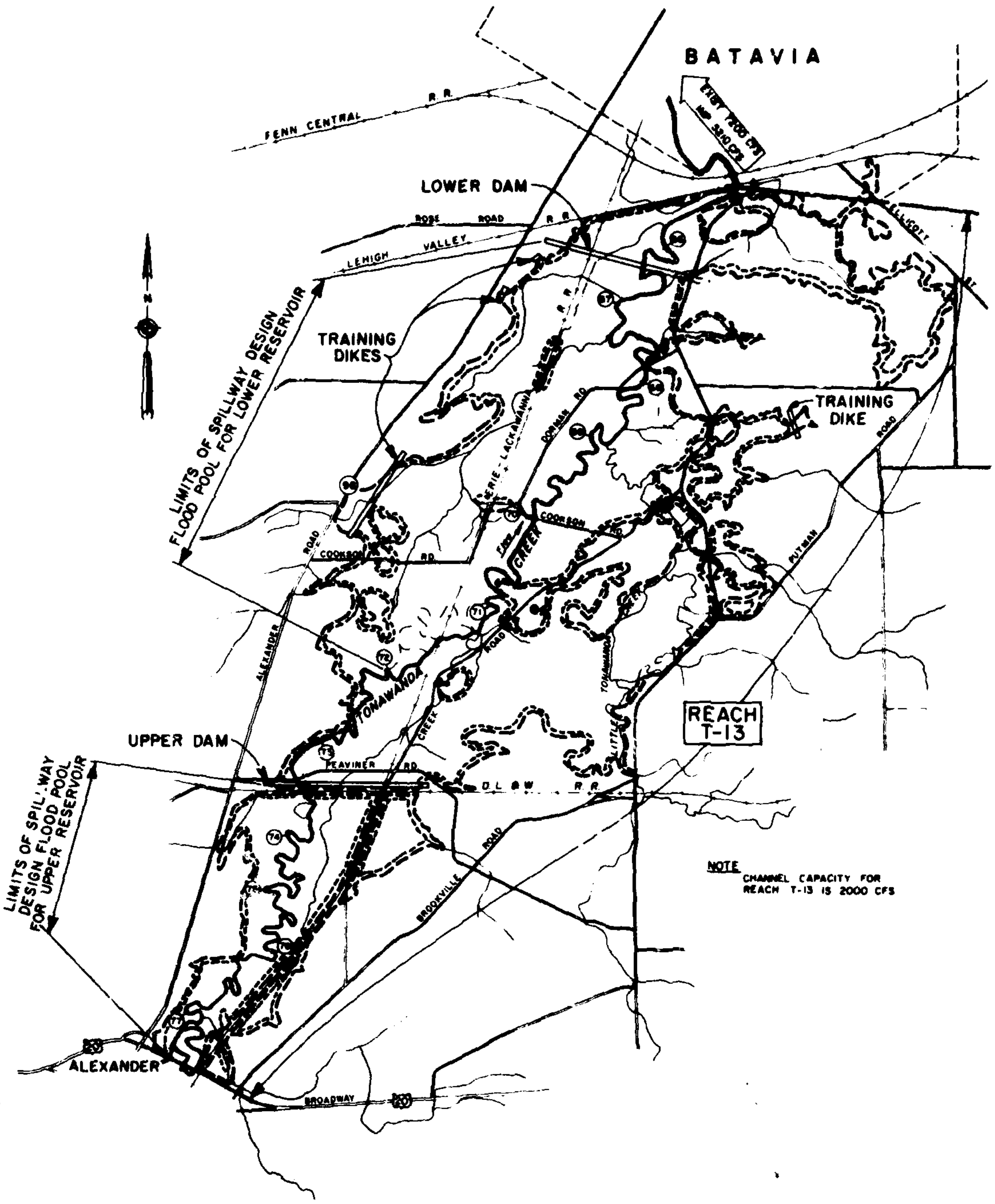


TONAWANDA GAME MANAGEMENT AREA
EXIST 7900 CFS
IMP 6490 CFS
LEWISTON ROAD
JUDGE ROAD
BLOOMINGDALE ROAD
ALLEGANY ROAD
CENTRAL R. R.
HOPKINS ROAD
TONAWANDA INDIAN RESERVATION
TONAWANDA CREEK
PENN
MARTIN RD
SPARLING ROAD
REACH
N
REACH T-12
KELSEY ROAD
MATCH LINE
BUSHVILLE
SOUTH MAIN ST.
TONAWANDA
WEST
RIVER
STREET
CITY LINE
WORTENDYKE ROAD
DONAHUE ROAD
PENN CENTRAL R. R.
PEARL
CONRAIL PENN
PENN CENTRAL R. R. (MAIN LINE)
SCALE OF FEET
1000 0 1000 2000 3000 4000



REACH	RANGE OF CHANNEL CAPACITY CFS
T-11 AND T-12	3200 - 4200
B-1 THRU B-5	6000

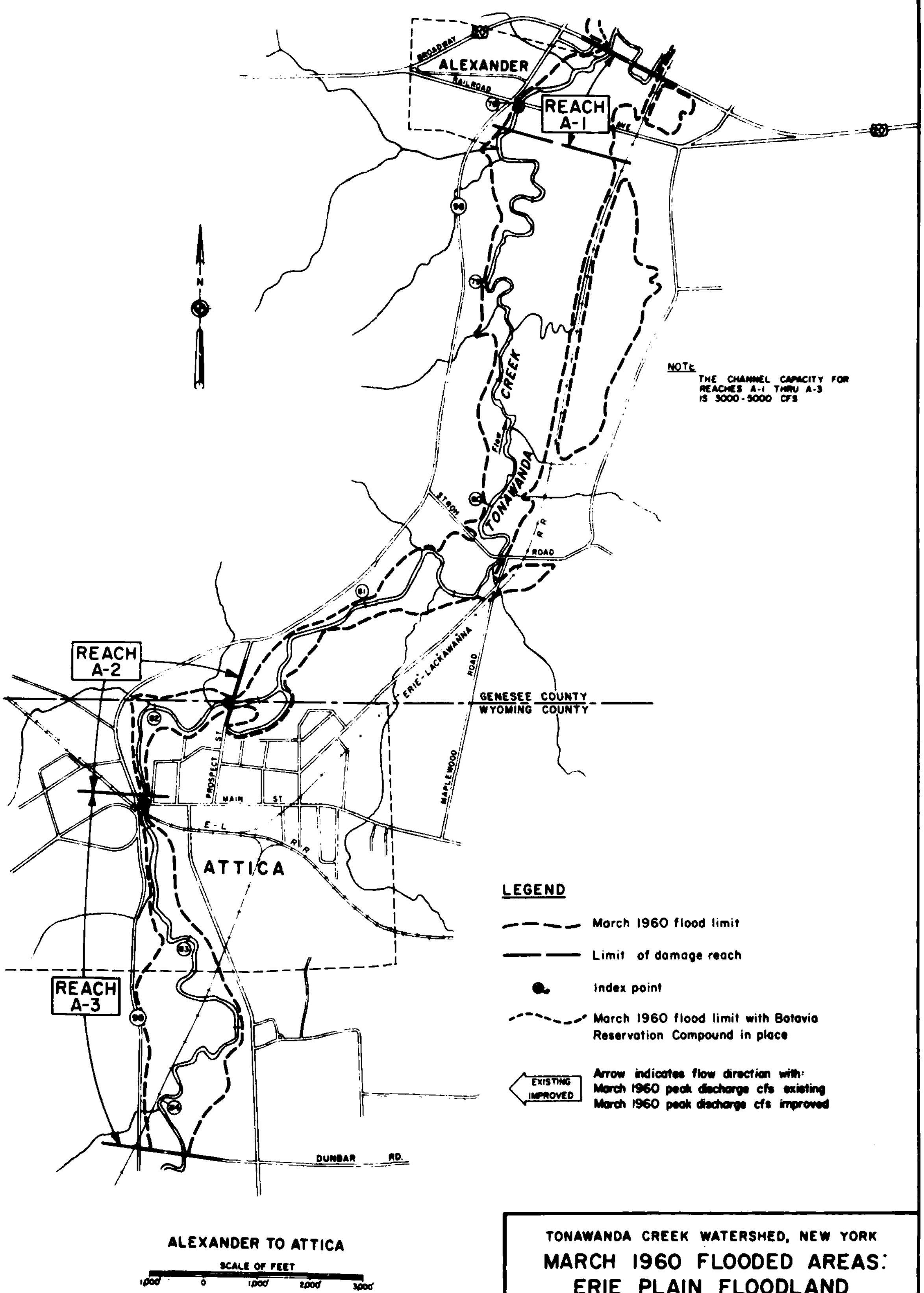
PLATE A1b



BATAVIA TO ALEXANDER

SCALE OF FEET

2,000 1,000 0 2,000 4,000 6,000

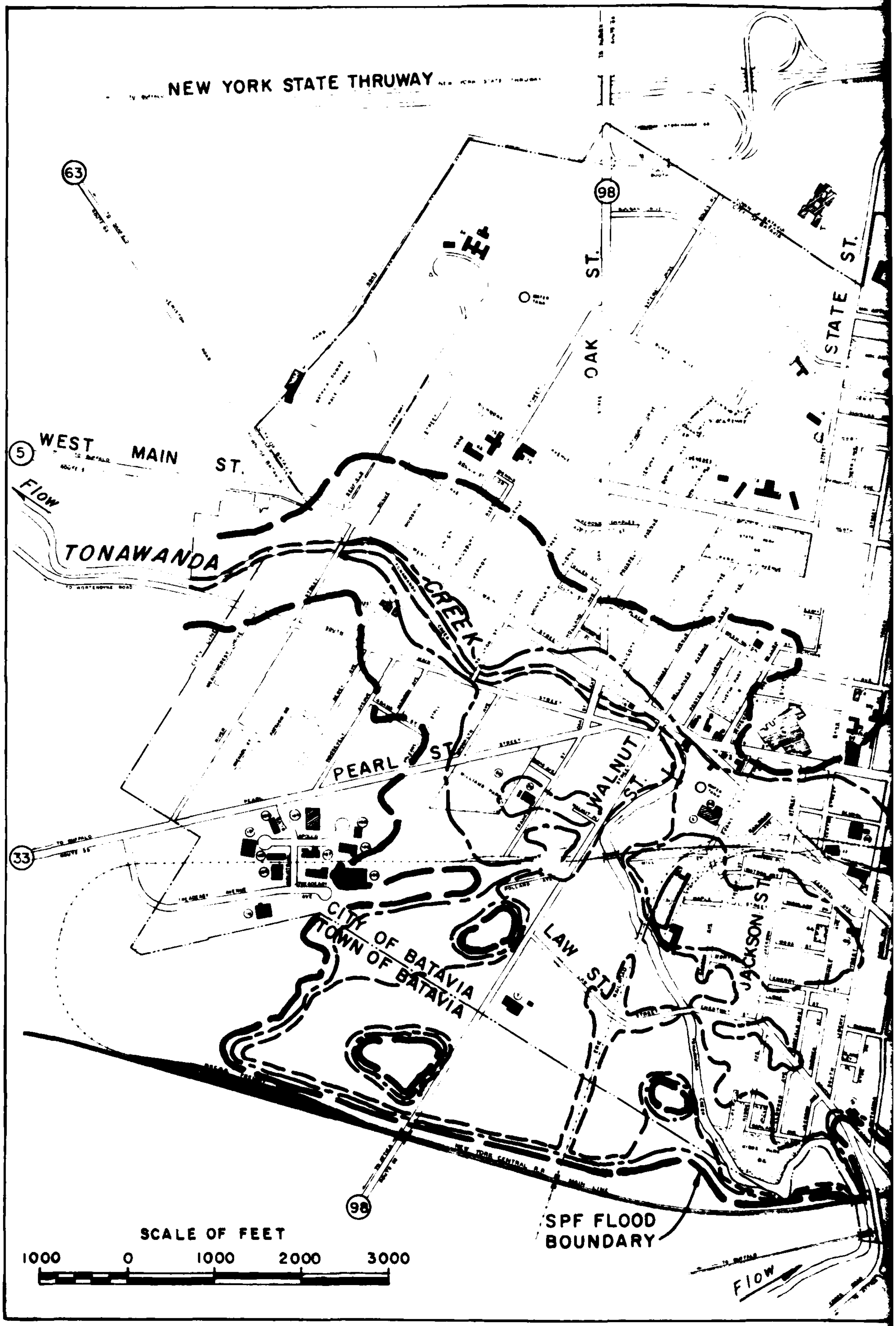


TONAWANDA CREEK WATERSHED, NEW YORK

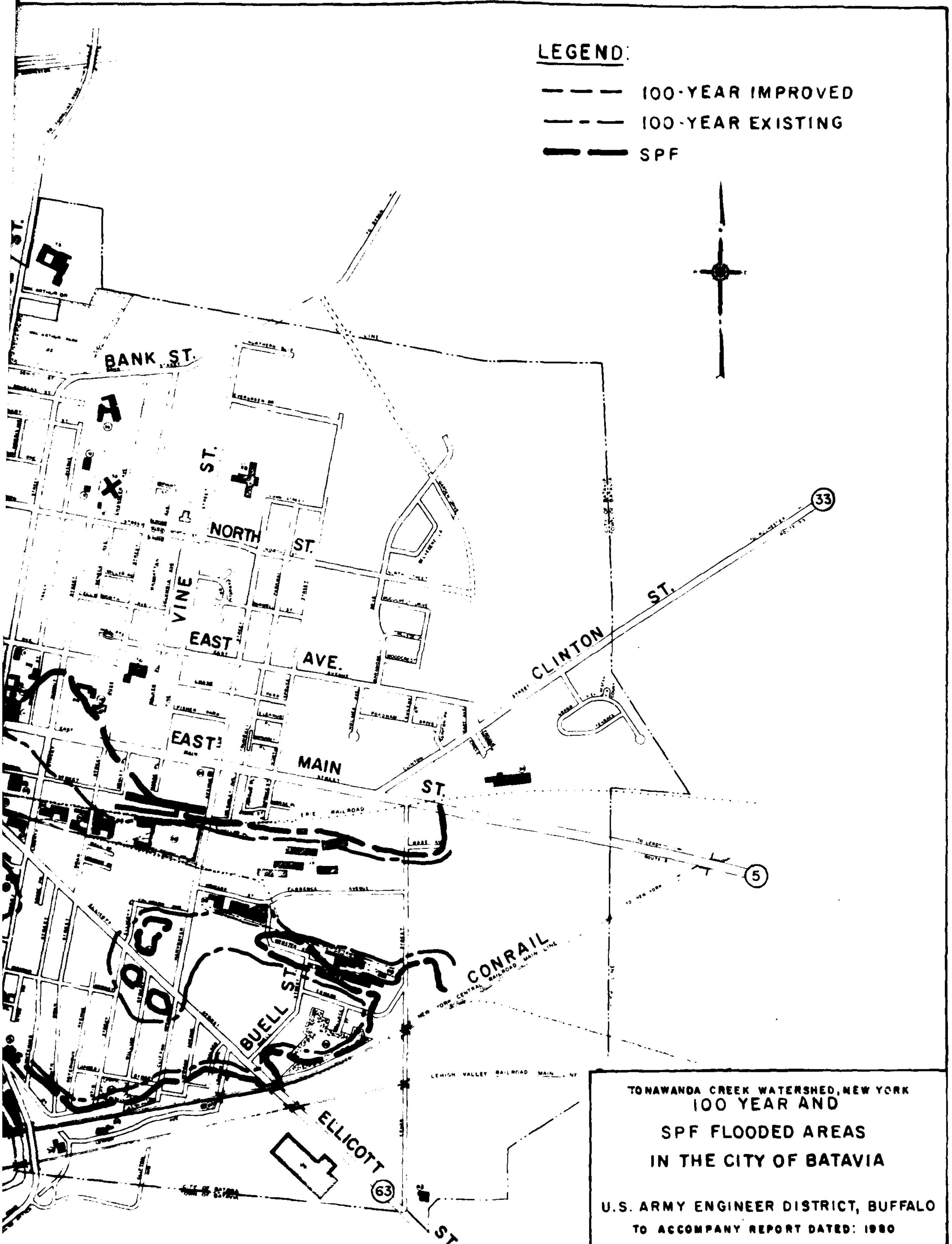
MARCH 1960 FLOODED AREAS: ERIE PLAIN FLOODLAND

(UPPER WATERSHED)

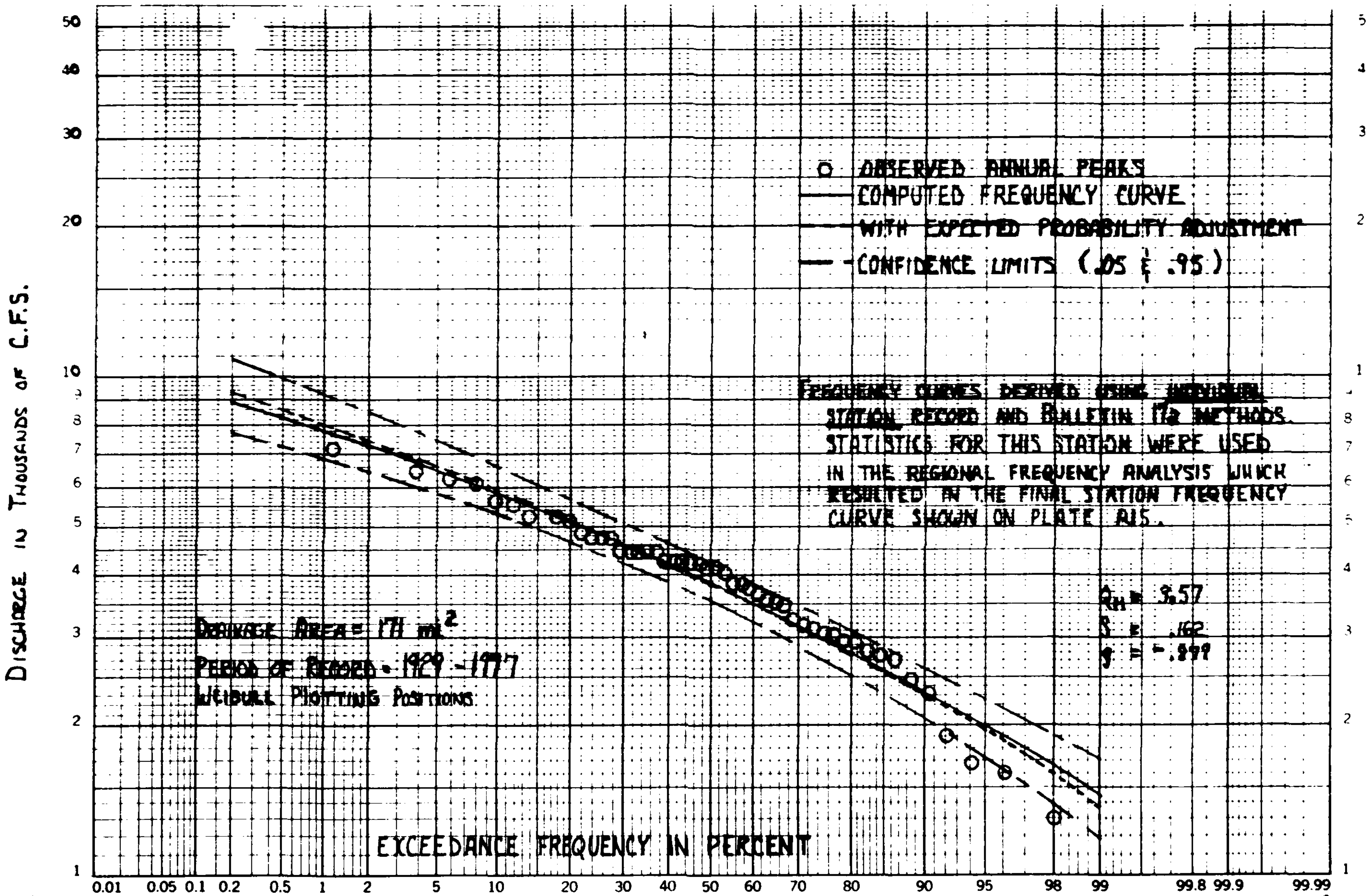
U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REVIEW OF REPORTS
DATED: 1980


NEW YORK STATE THRUWAY
63
98
ST.
OAK
STATE
ST.
5
WEST MAIN ST.
Flow
TONAWANDA
CREEK
PEARL ST.
WALNUT ST.
33
CITY OF BATAVIA
TOWN OF BATAVIA
LAW ST.
JACKSON ST.
98
SCALE OF FEET
1000 0 1000 2000 3000
SPF FLOOD BOUNDARY
Flow

1


LEGEND:
100-YEAR IMPROVED
100-YEAR EXISTING
SPF
BANK ST.
ST.
VINE
NORTH
ST.
EAST
AVE.
EAST
MAIN
ST.
CLINTON
ST.
33
5
ERIE RAILROAD
CONRAIL
NEW YORK CENTRAL RAILROAD MAIN LINE
BUELL ST.
LEHIGH VALLEY RAILROAD MAIN LINE
ELLICOTT
ST.
63
TONAWANDA CREEK WATERSHED, NEW YORK
100 YEAR AND
SPF FLOODED AREAS
IN THE CITY OF BATAVIA
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1980

9



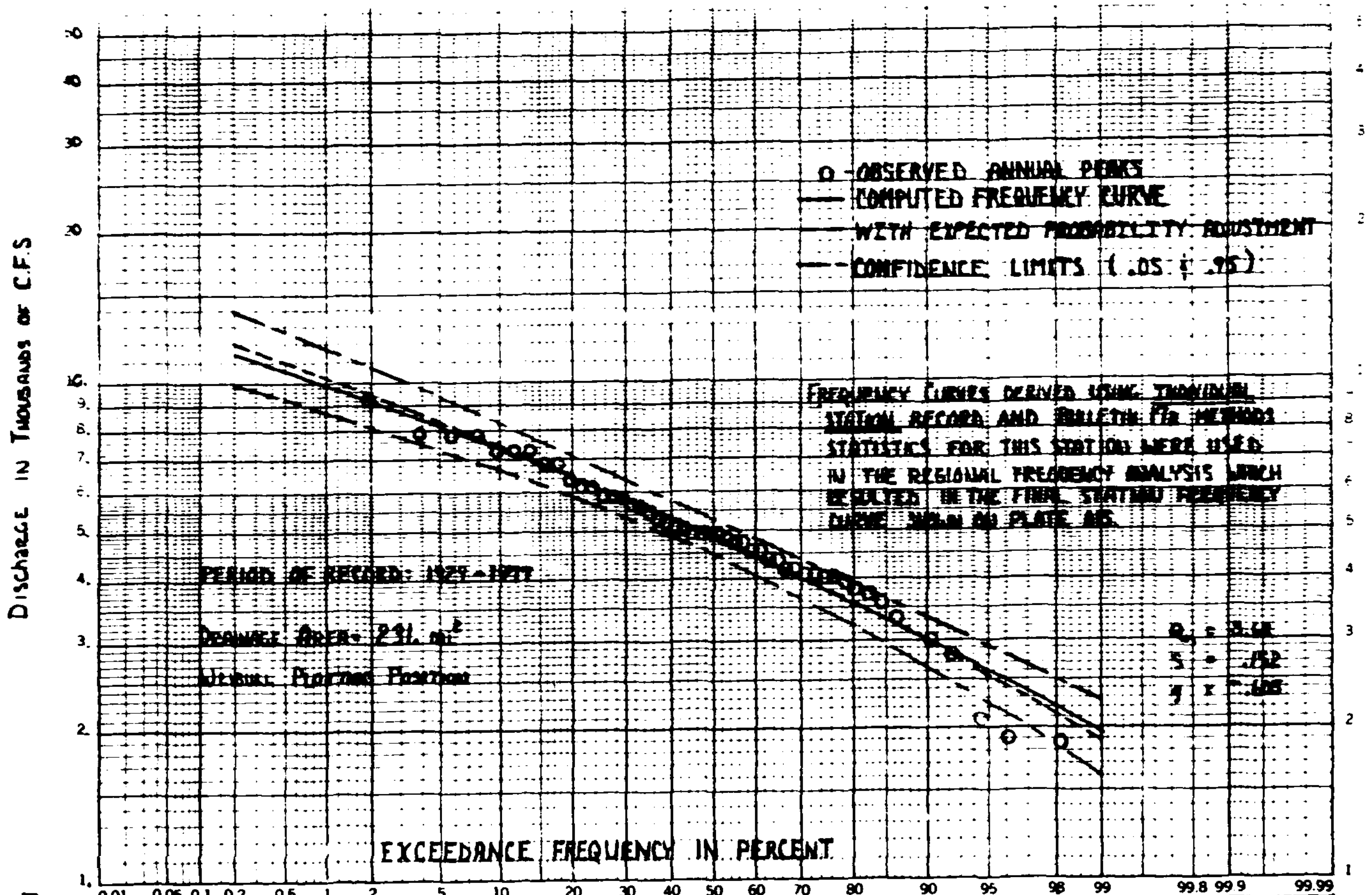
TONAWANDA CREEK WATERSHED, N. Y.

PEAK DISCHARGE-FREQUENCY CURVE

TON. CR. AT BATAVIA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A2



TONAWANDA CREEK WATERSHED, N. Y.

PEAK DISCHARGE-
FREQUENCY CURVE

TON. CR. AT ALABAMA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A3

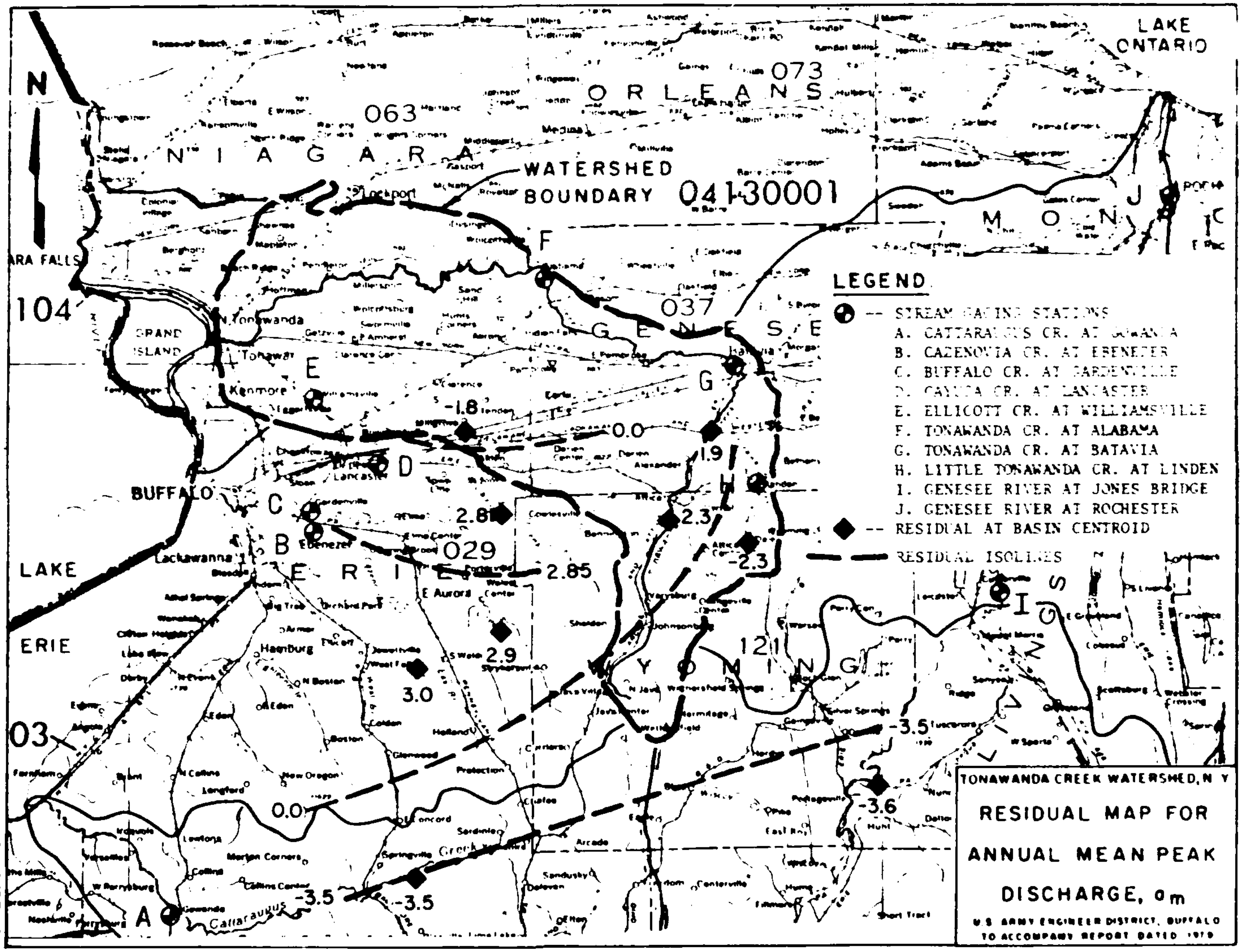
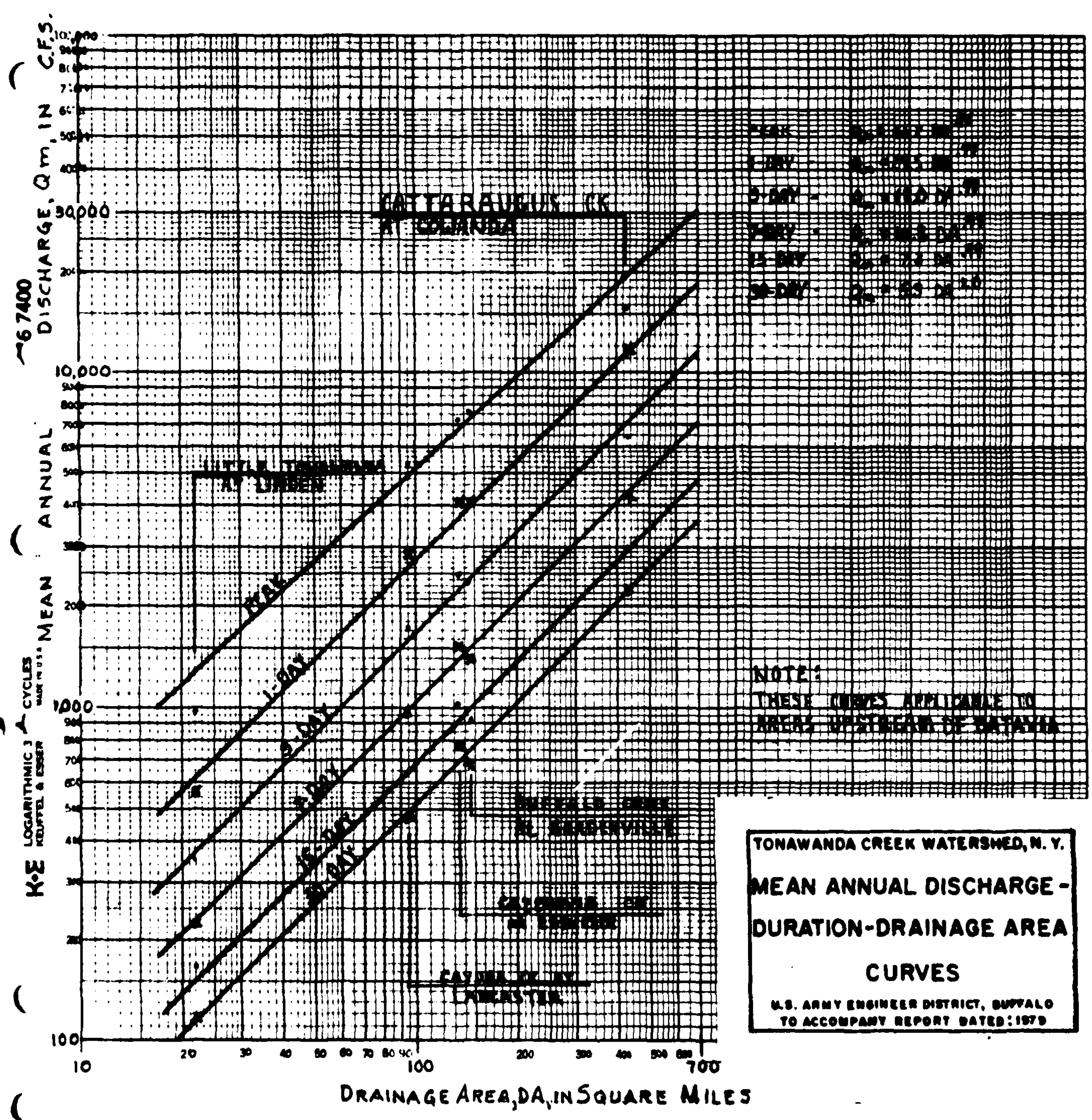
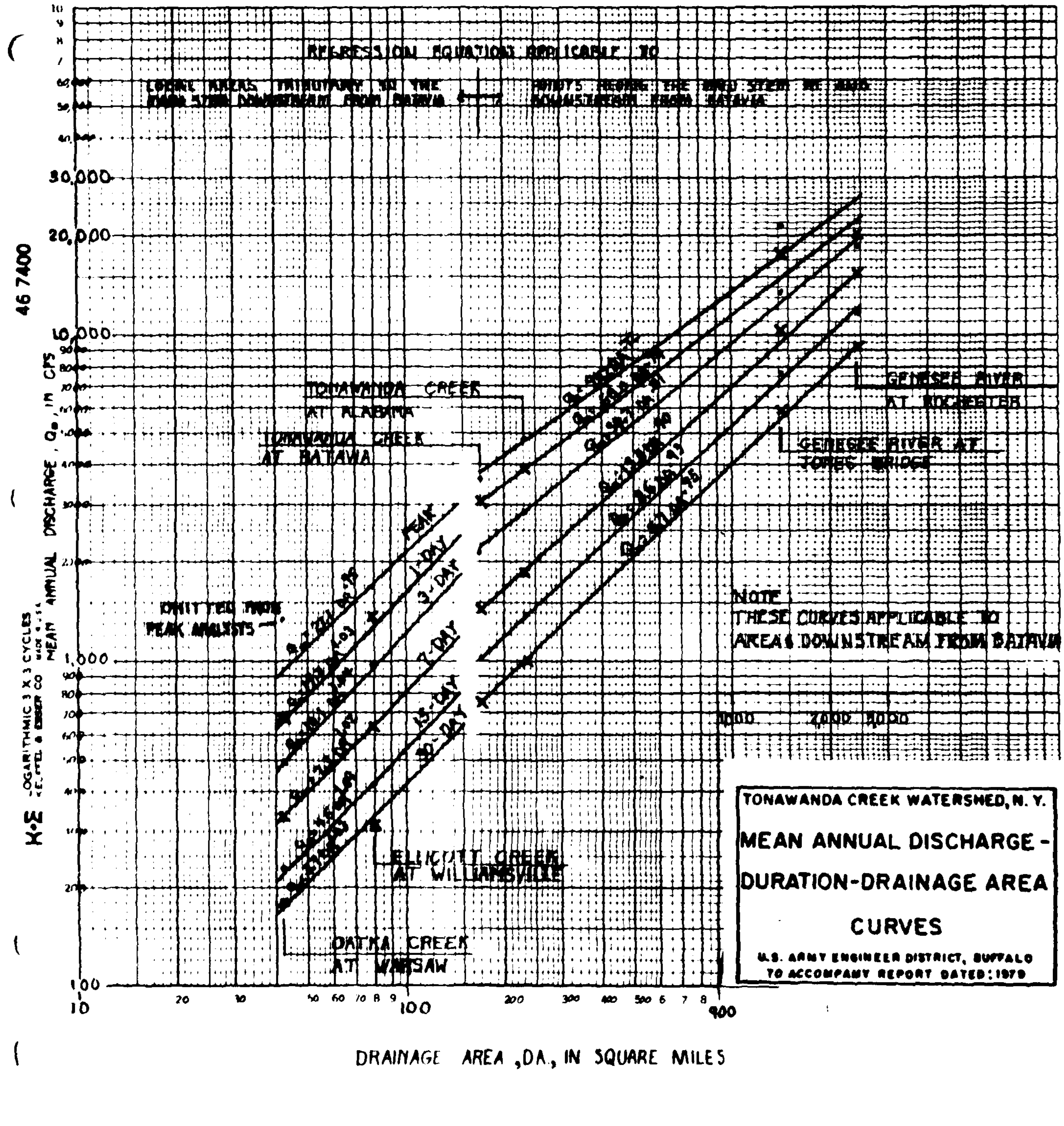

LAKE ONTARIO
N
ORLEANS
073
063
NIAGARA
WATERSHED BOUNDARY
04130001
MONROE
LEGEND
STREAM GAGING STATIONS
A. CATTARAUGUS CR. AT GOWANDA
B. CAZENOVIA CR. AT EBENEZER
C. BUFFALO CR. AT GARDENVILLE
D. CAYUGA CR. AT LANCASTER
E. ELLICOTT CR. AT WILLIAMSVILLE
F. TONAWANDA CR. AT ALABAMA
G. TONAWANDA CR. AT BATAVIA
H. LITTLE TONAWANDA CR. AT LINDEN
I. GENESEE RIVER AT JONES BRIDGE
J. GENESEE RIVER AT ROCHESTER
RESIDUAL AT BASIN CENTROID
RESIDUAL ISOLINES
104
GRAND ISLAND
BUFFALO
LAKE ERIE
GENESEE
037
ERIE
029
WYOMING
121
LIVINGSTON
03
-1.8
0.0
1.9
2.8
2.85
2.3
-2.3
2.9
3.0
0.0
-3.5
-3.5
-3.5
-3.6
Lockport
Tonawanda
Kenmore
Lackawanna
Batavia
Cattaraugus
TONAWANDA CREEK WATERSHED, N.Y.
RESIDUAL MAP FOR ANNUAL MEAN PEAK DISCHARGE, σ_m
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED 1979

PLATE A4a



TONAWANDA CREEK WATERSHED, N. Y.
MEAN ANNUAL DISCHARGE - DURATION-DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
MEAN ANNUAL DISCHARGE, Qm, IN C.F.S.
DRAINAGE AREA, DA, IN SQUARE MILES
CATTARAUGUS CK AT GOWANDA
PEAK
1-DAY
NOTE:
THESE CURVES APPLICABLE TO AREAS UPSTREAM OF BATAVIA
K•E LOGARITHMIC 3 CYCLES KEUFFEL & ESSER

PLATE A46



TONAWANDA CREEK WATERSHED, N. Y.

MEAN ANNUAL DISCHARGE - DURATION-DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A4c

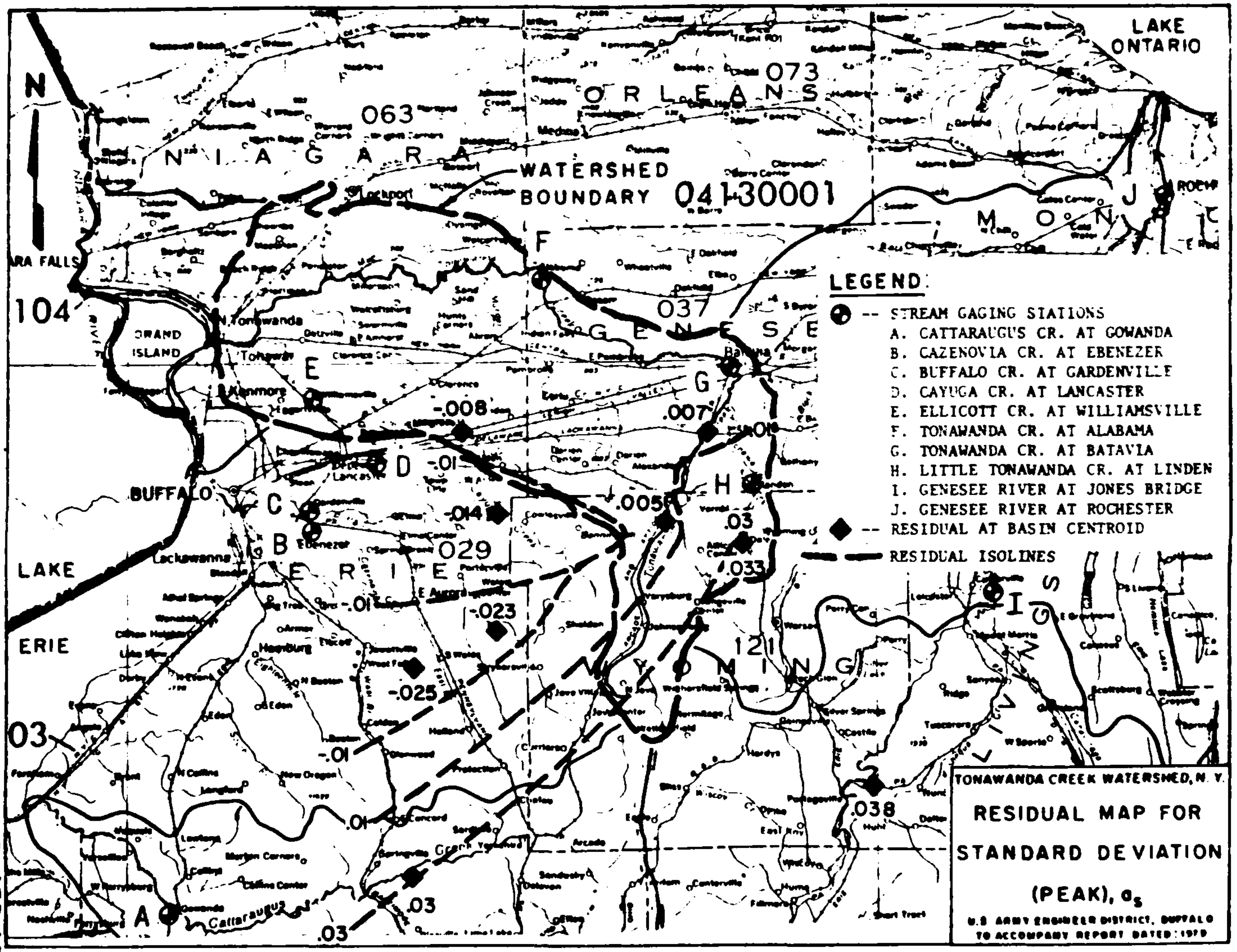
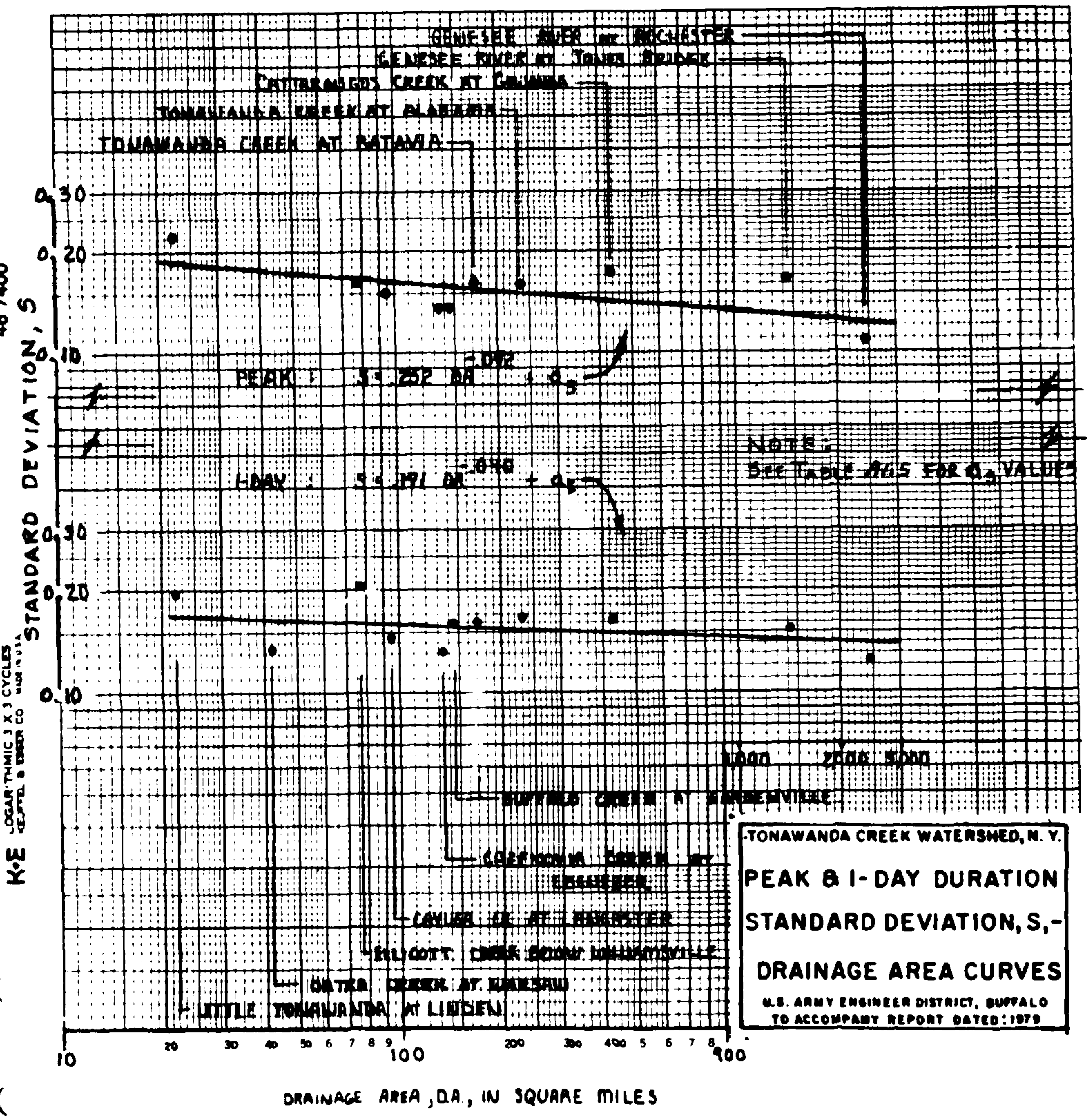

LAKE ONTARIO
ORLEANS
NIAGARA
GENESEE
MONROE
WYOMING
LIVINGSTON
ERIE
LAKE ERIE
GRAND ISLAND
BUFFALO
WATERSHED BOUNDARY 04130001
063
073
037
104
03
.007
.01
-.008
-.01
-.014
029
.005
.03
.033
-.023
-.025
-.01
.01
.03
121
.038
LEGEND
-- STREAM GAGING STATIONS
A. CATTARAUGUS CR. AT GOWANDA
B. CAZENOVIA CR. AT EBENEZER
C. BUFFALO CR. AT GARDENVILLE
D. CAYUGA CR. AT LANCASTER
E. ELLICOTT CR. AT WILLIAMSVILLE
F. TONAWANDA CR. AT ALABAMA
G. TONAWANDA CR. AT BATAVIA
H. LITTLE TONAWANDA CR. AT LINDEN
I. GENESEE RIVER AT JONES BRIDGE
J. GENESEE RIVER AT ROCHESTER
-- RESIDUAL AT BASIN CENTROID
RESIDUAL ISOLINES
TONAWANDA CREEK WATERSHED, N. Y.
RESIDUAL MAP FOR
STANDARD DEVIATION
(PEAK), σ_s
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

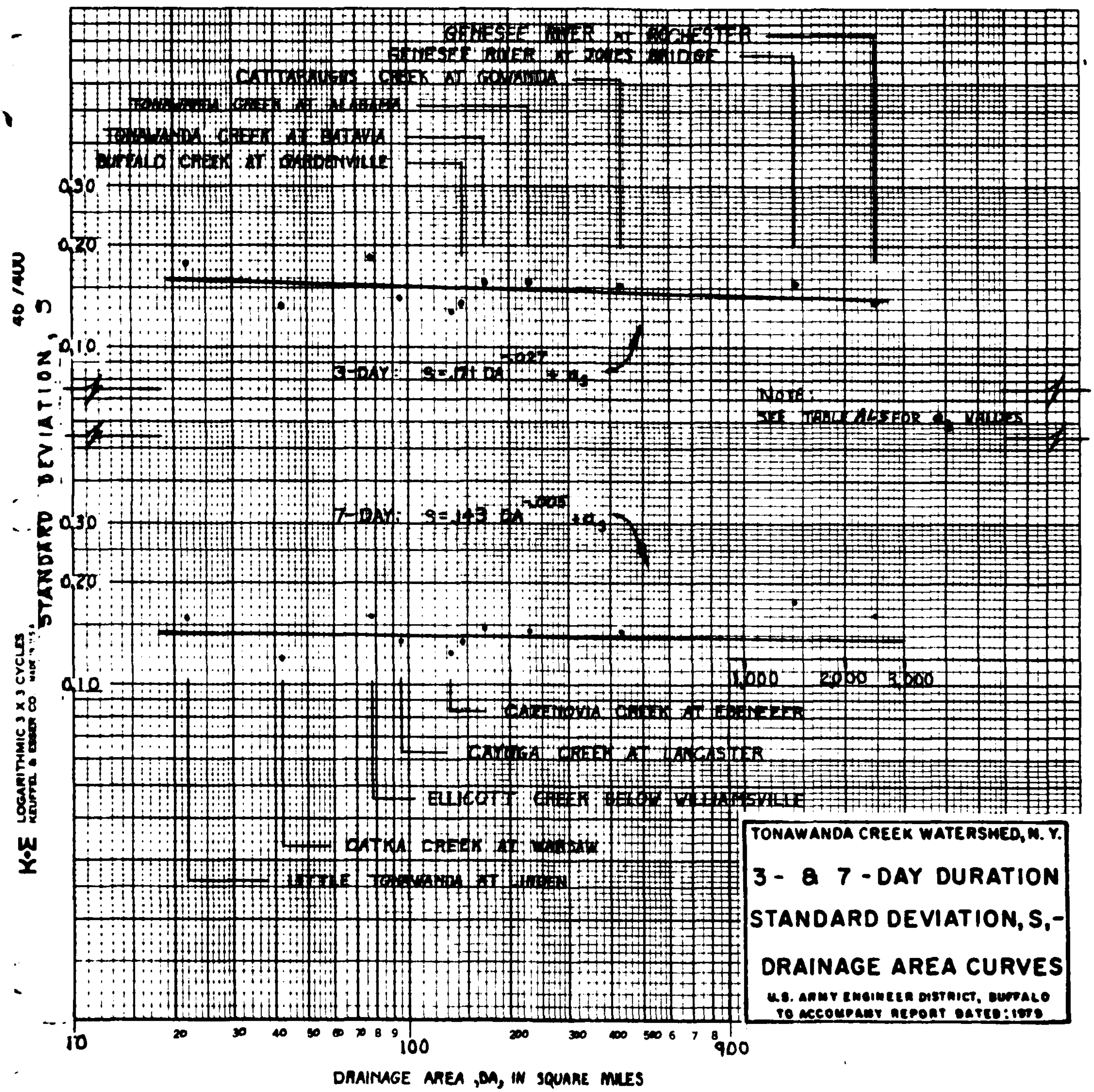
PLATE A5



TONAWANDA CREEK WATERSHED, N. Y.

PEAK & 1-DAY DURATION STANDARD DEVIATION, S, - DRAINAGE AREA CURVES

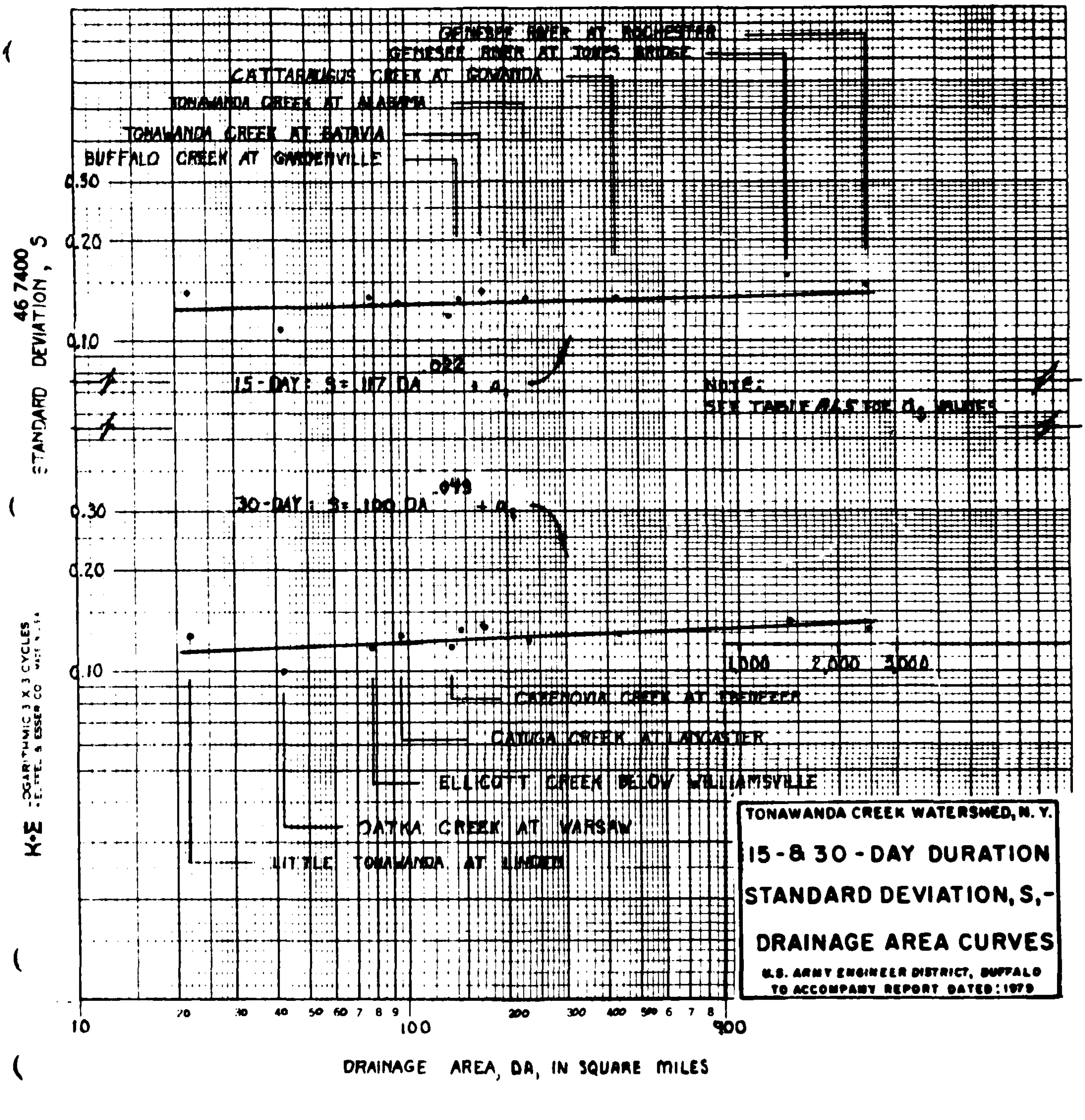
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, N. Y.

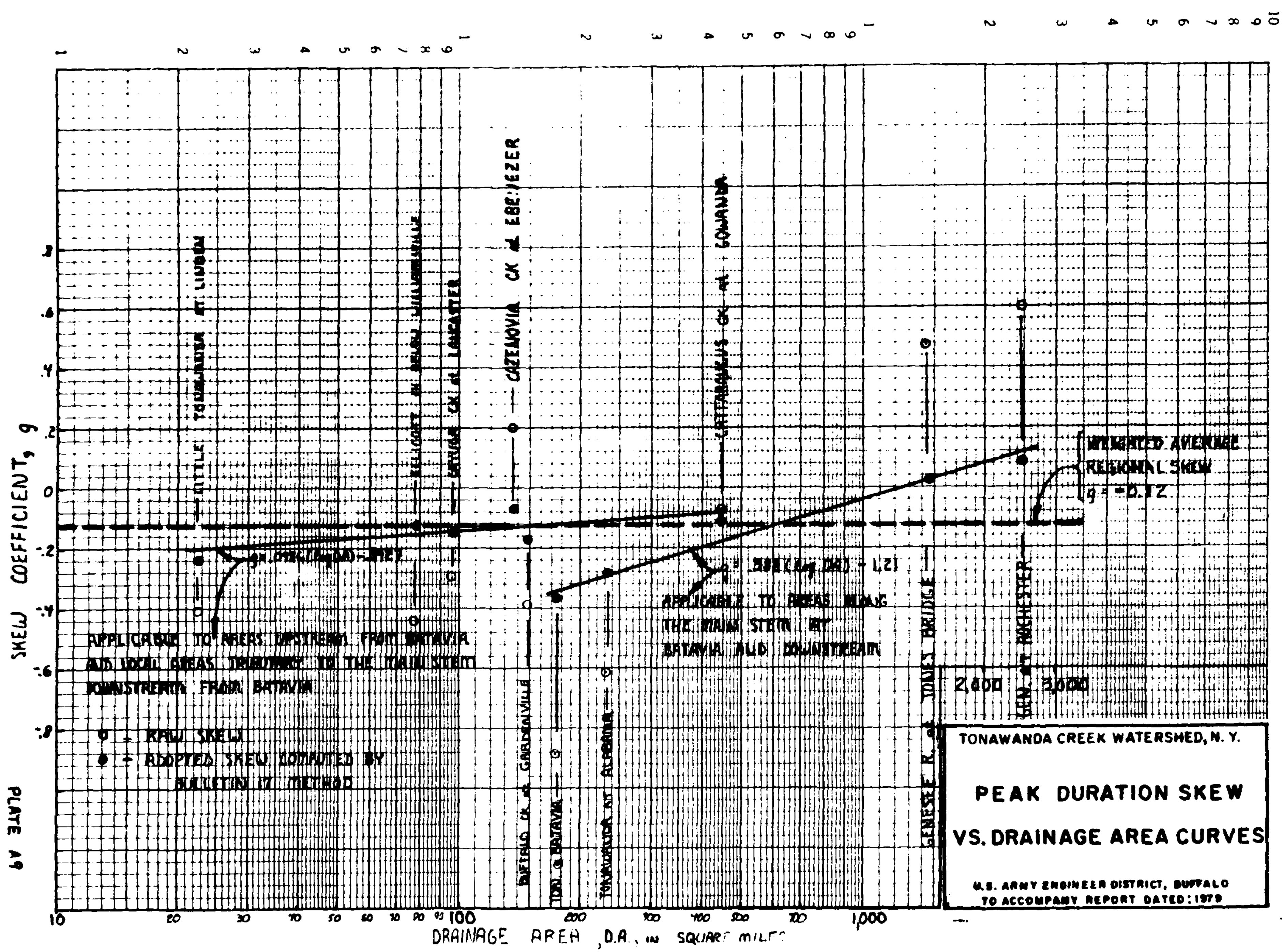
3- & 7-DAY DURATION STANDARD DEVIATION, S,- DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



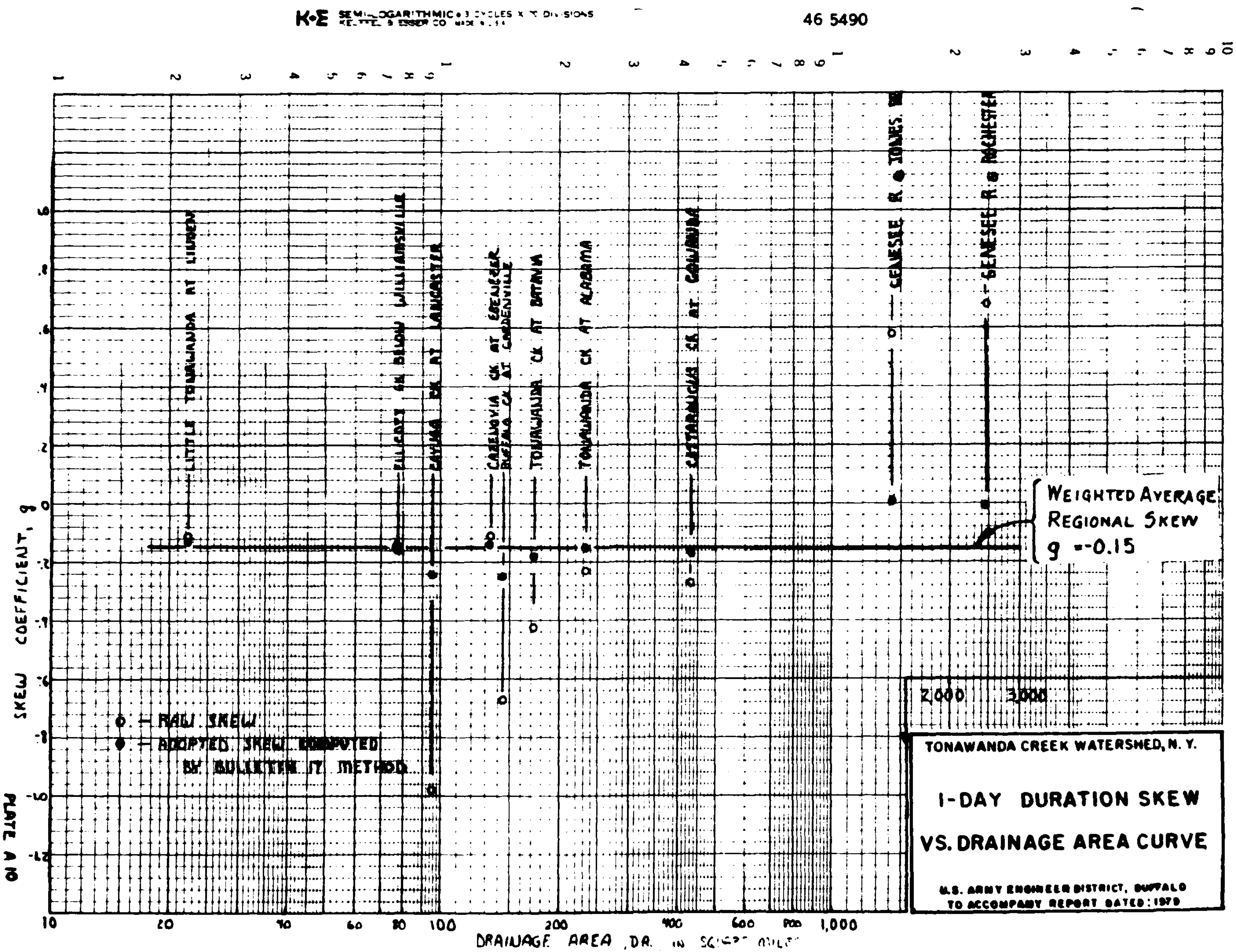
GENESEE RIVER AT ROCHESTER
GENESEE RIVER AT JONES BRIDGE
CATTARAUGUS CREEK AT GOWANDA
TONAWANDA CREEK AT ALABAMA
TONAWANDA CREEK AT BATAVIA
BUFFALO CREEK AT GARDENVILLE
STANDARD DEVIATION, S
0.30
0.20
0.10
15-DAY: S = .117 DA^.022 + a_s
NOTE:
SEE TABLE A.5 FOR a_s VALUES
30-DAY: S = .100 DA^.043 + a_s
1,000
2,000
3,000
CAZENOVIA CREEK AT EBENEZER
CAYUGA CREEK AT LANCASTER
ELLICOTT CREEK BELOW WILLIAMSVILLE
OATKA CREEK AT WARSAW
LITTLE TONAWANDA AT LINDEN
10
20
30
40
50
60
7
8
9
100
200
300
400
500
6
7
8
900
DRAINAGE AREA, DA, IN SQUARE MILES
TONAWANDA CREEK WATERSHED, N. Y.
15-& 30-DAY DURATION
STANDARD DEVIATION, S,-
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
K·E LOGARITHMIC 3 X 3 CYCLES
46 7400

PLATE A8



TONAWANDA CREEK WATERSHED, N. Y.
PEAK DURATION SKEW
VS. DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
SKEW COEFFICIENT, g
DRAINAGE AREA, D.A., IN SQUARE MILES
WEIGHTED AVERAGE
REGIONAL SKEW
g = -0.12
APPLICABLE TO AREAS UPSTREAM FROM BATAVIA
AND LOCAL AREAS TRIBUTARY TO THE MAIN STEM
DOWNSTREAM FROM BATAVIA
APPLICABLE TO AREAS ALONG
THE MAIN STEM AT
BATAVIA AND DOWNSTREAM
RAW SKEW
ADOPTED SKEW COMPUTED BY
BULLETIN 17 METHOD
LITTLE TONAWANDA AT LINDEN
CAYUGA CK at LANCASTER
CAZENOVIA CK at EBENEZER
BUFFALO CK at GARDENVILLE
TON. @ BATAVIA
TONAWANDA AT ALABAMA
CATTARAUGUS CK at GOWANDA
GENESEE R. at JONES BRIDGE
GEN. at ROCHESTER

PLATE A9



K+E SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 5490
LITTLE TONAWANDA AT LINDEN
ELLICOTT CK BELOW WILLIAMSVILLE
CAYUGA CK AT LANCASTER
CAZENOVIA CK AT EBENEZER
BUFFALO CK AT GARDENVILLE
TONAWANDA CK AT BATAVIA
TONAWANDA CK AT ALABAMA
CATTARAUGUS CK AT GOWANDA
GENESEE R @ JONES BR
GENESEE R @ ROCHESTER
WEIGHTED AVERAGE
REGIONAL SKEW
g = -0.15
o — RAW SKEW
● — ADOPTED SKEW COMPUTED
BY BULLETIN 17 METHOD
SKEW COEFFICIENT, g
DRAINAGE AREA, DA, IN SQUARE MILES
2000
3000
TONAWANDA CREEK WATERSHED, N. Y.
1-DAY DURATION SKEW
VS. DRAINAGE AREA CURVE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A 10

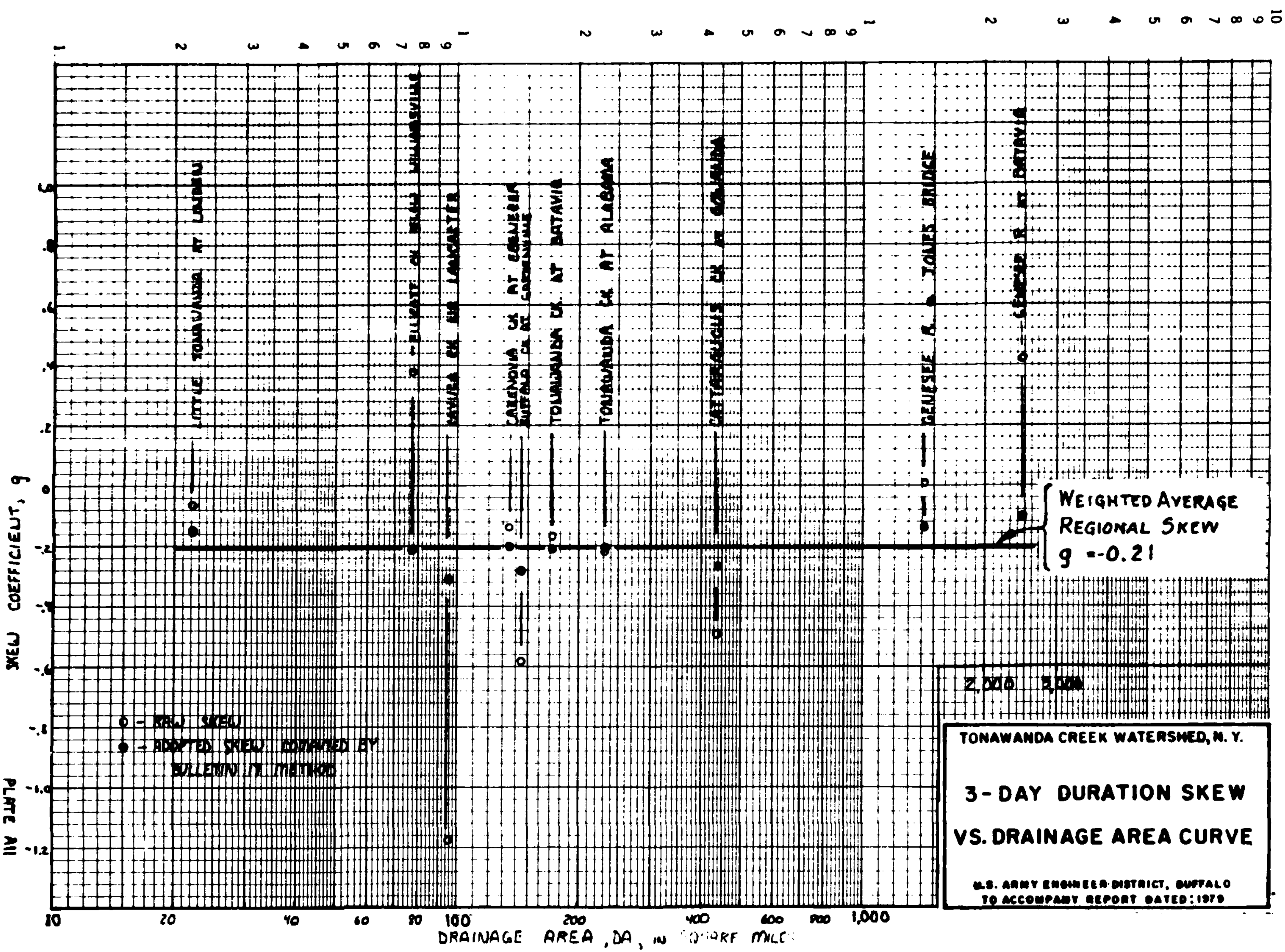
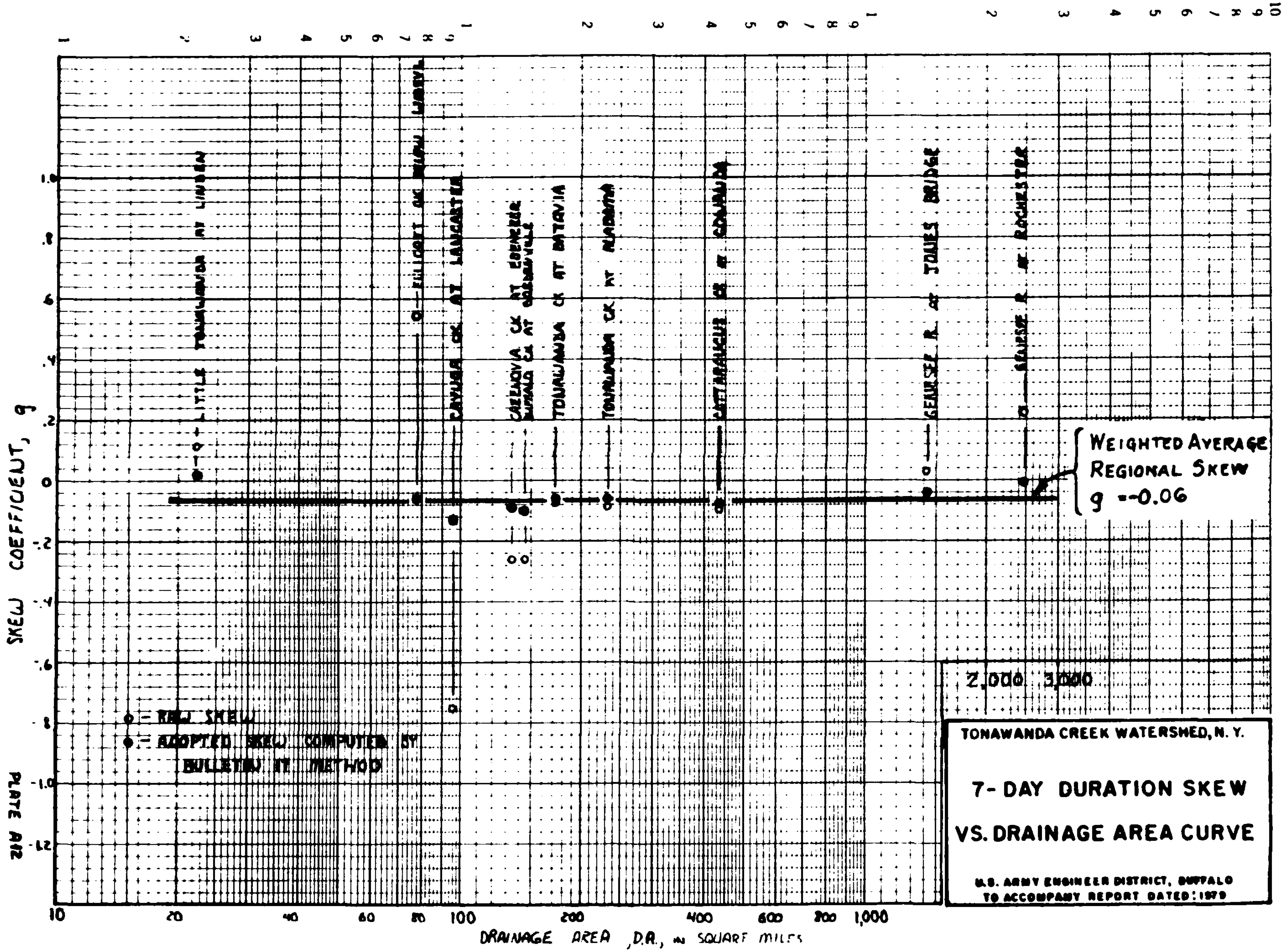

LITTLE TONAWANDA AT LINDEN
ELLICOTT CK BELOW WILLIAMSVILLE
CAYUGA CK NR LANCASTER
CAZENOVIA CK AT EBENEZER
BUFFALO CK AT GARDENVILLE
TONAWANDA CK AT BATAVIA
TONAWANDA CK AT ALABAMA
CATTARAUGUS CK AT GOWANDA
GENESEE R. @ JONES BRIDGE
GENESEE R AT BATAVIA
WEIGHTED AVERAGE
REGIONAL SKEW
g =-0.21
o - RAW SKEW
● - ADOPTED SKEW COMPUTED BY
BULLETIN 17 METHOD
SKEW COEFFICIENT, g
DRAINAGE AREA, DA, IN SQUARE MILES
TONAWANDA CREEK WATERSHED, N. Y.
3-DAY DURATION SKEW
VS. DRAINAGE AREA CURVE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A11



TONAWANDA CREEK WATERSHED, N. Y.

7-DAY DURATION SKEW VS. DRAINAGE AREA CURVE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A12

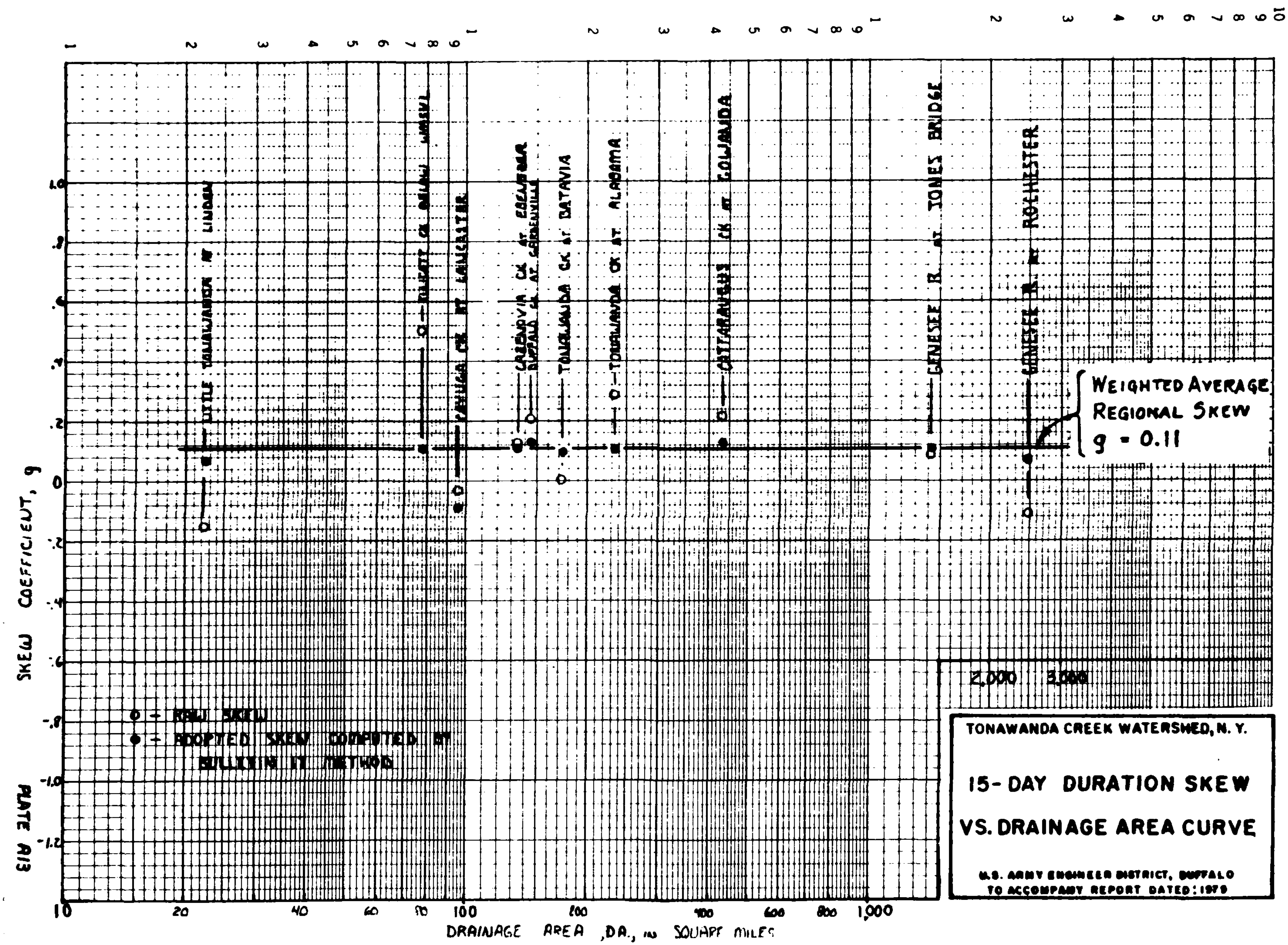
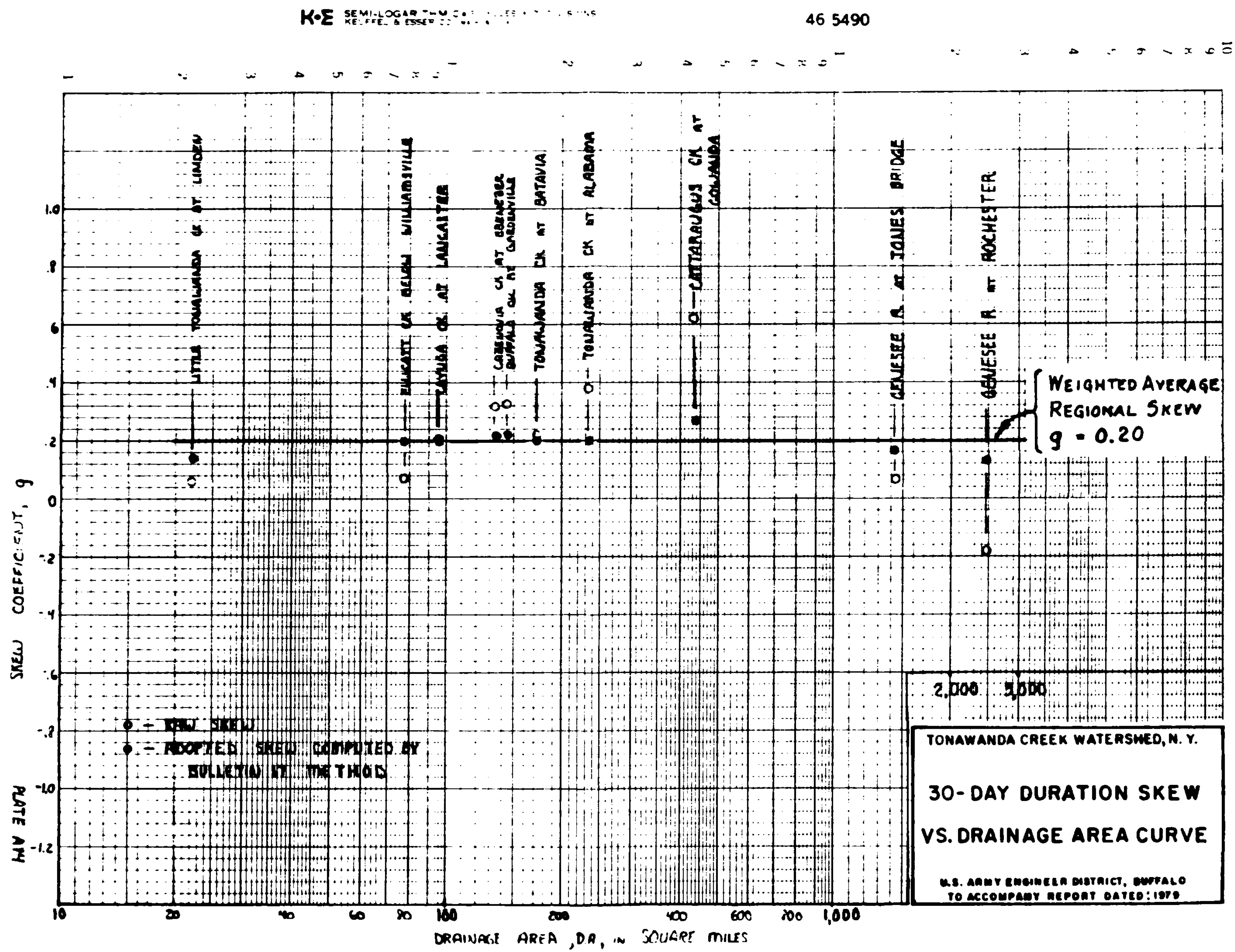
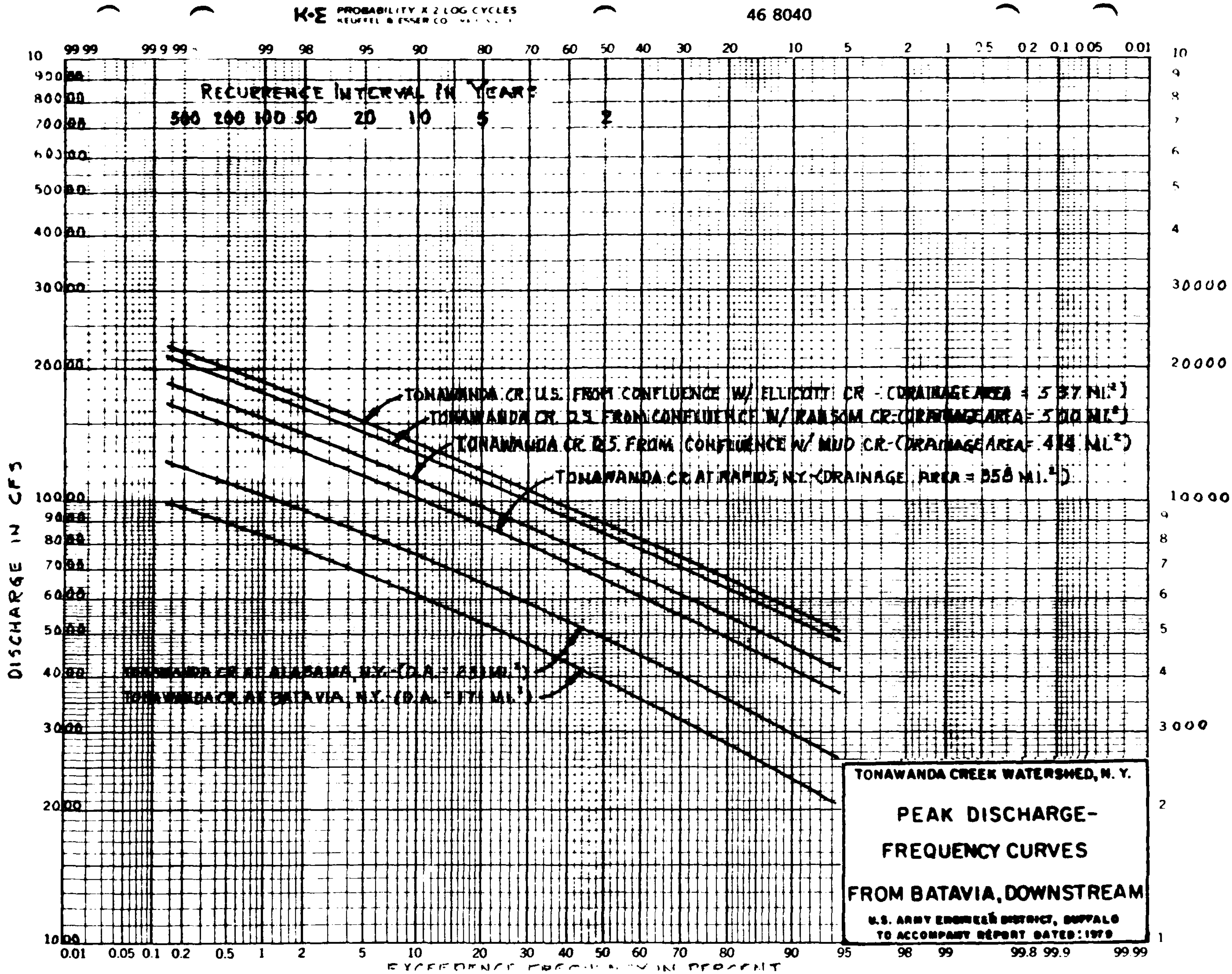

TONAWANDA CREEK WATERSHED, N. Y.
15-DAY DURATION SKEW
VS. DRAINAGE AREA CURVE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
WEIGHTED AVERAGE
REGIONAL SKEW
g = 0.11
○ - RAW SKEW
● - ADOPTED SKEW COMPUTED BY
BULLETIN 17 METHOD
LITTLE TONAWANDA AT LINDEN
CAYUGA CK AT LANCASTER
CAZENOVIA CK AT EBENEZER
BUFFALO CK AT GARDENVILLE
TONAWANDA CK AT BATAVIA
TONAWANDA CK AT ALABAMA
CATTARAUGUS CK AT GOWANDA
GENESEE R. AT JONES BRIDGE
GENESEE R. AT ROCHESTER
SKEW COEFFICIENT, g
DRAINAGE AREA, DA., IN SQUARE MILES
10
20
40
60
80
100
200
400
600
800
1,000
2,000
3,000
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
KEUFFEL & ESSER CO.

PLATE A13



K·E SEMI-LOGARITHMIC
46 5490
LITTLE TONAWANDA CK AT LINDEN
ELLICOTT CK BELOW WILLIAMSVILLE
CAYUGA CK AT LANCASTER
CASSADAGA CK AT GENESEE
BUFFALO CK AT GARDENVILLE
TONAWANDA CK AT BATAVIA
TONAWANDA CK AT ALABAMA
CATTARAUGUS CK AT GOWANDA
GENESEE R AT JONES BRIDGE
GENESEE R AT ROCHESTER
WEIGHTED AVERAGE
REGIONAL SKEW
g = 0.20
SKEW COEFFICIENT, g
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
○ - RAW SKEW
● - ADOPTED SKEW COMPUTED BY
BULLETIN 17 METHOD
10
20
40
60
80
100
200
400
600
800
1,000
2,000
3,000
DRAINAGE AREA, DA, IN SQUARE MILES
PLATE A14
TONAWANDA CREEK WATERSHED, N. Y.
30-DAY DURATION SKEW
VS. DRAINAGE AREA CURVE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



K-E PROBABILITY X 2 LOG CYCLES
46 8040
RECURRENCE INTERVAL IN YEARS
500 200 100 50 20 10 5 2
TONAWANDA CR. U.S. FROM CONFLUENCE W/ ELLICOTT CR. - (DRAINAGE AREA = 537 MI.²)
TONAWANDA CR. D.S. FROM CONFLUENCE W/ RANSOM CR.-(DRAINAGE AREA = 500 MI.²)
TONAWANDA CR. D.S. FROM CONFLUENCE W/ MUD CR.-(DRAINAGE AREA = 414 MI.²)
TONAWANDA CR. AT RAPIDS, N.Y.-(DRAINAGE AREA = 350 MI.²)
TONAWANDA CR. AT ALABAMA, N.Y.-(D.A. = 231 MI.²)
TONAWANDA CR. AT BATAVIA, N.Y. (D.A. = 171 MI.²)
DISCHARGE IN CFS
EXCEEDENCE FREQUENCY IN PERCENT
TONAWANDA CREEK WATERSHED, N. Y.
PEAK DISCHARGE-FREQUENCY CURVES
FROM BATAVIA, DOWNSTREAM
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A15

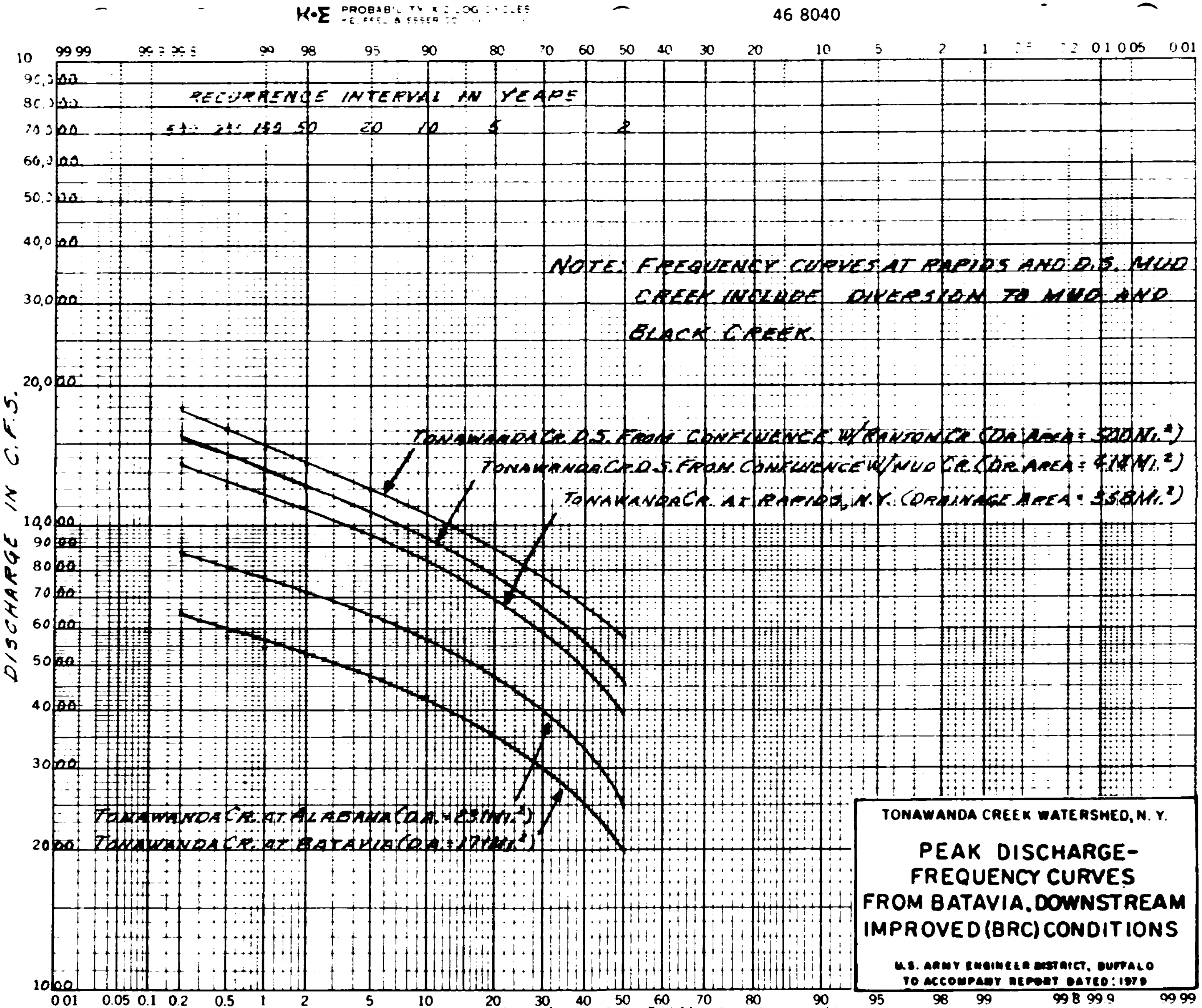

K•E PROBABILITY X 2 LOG CYCLES
46 8040
RECURRENCE INTERVAL IN YEARS
NOTE: FREQUENCY CURVES AT RAPIDS AND D.S. MUD CREEK INCLUDE DIVERSION TO MUD AND BLACK CREEK.
TONAWANDA CR. D.S. FROM CONFLUENCE W/RANSOM CR. (DR. AREA = 300 MI.²)
TONAWANDA CR. D.S. FROM CONFLUENCE W/MUD CR. (DR. AREA = 414 MI.²)
TONAWANDA CR. AT RAPIDS, N.Y. (DRAINAGE AREA = 358 MI.²)
TONAWANDA CR. AT ALABAMA (D.A. = 251 MI.²)
TONAWANDA CR. AT BATAVIA (D.A. = 171 MI.²)
DISCHARGE IN C.F.S.
TONAWANDA CREEK WATERSHED, N. Y.
PEAK DISCHARGE-FREQUENCY CURVES FROM BATAVIA, DOWNSTREAM IMPROVED (BRC) CONDITIONS
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A15a

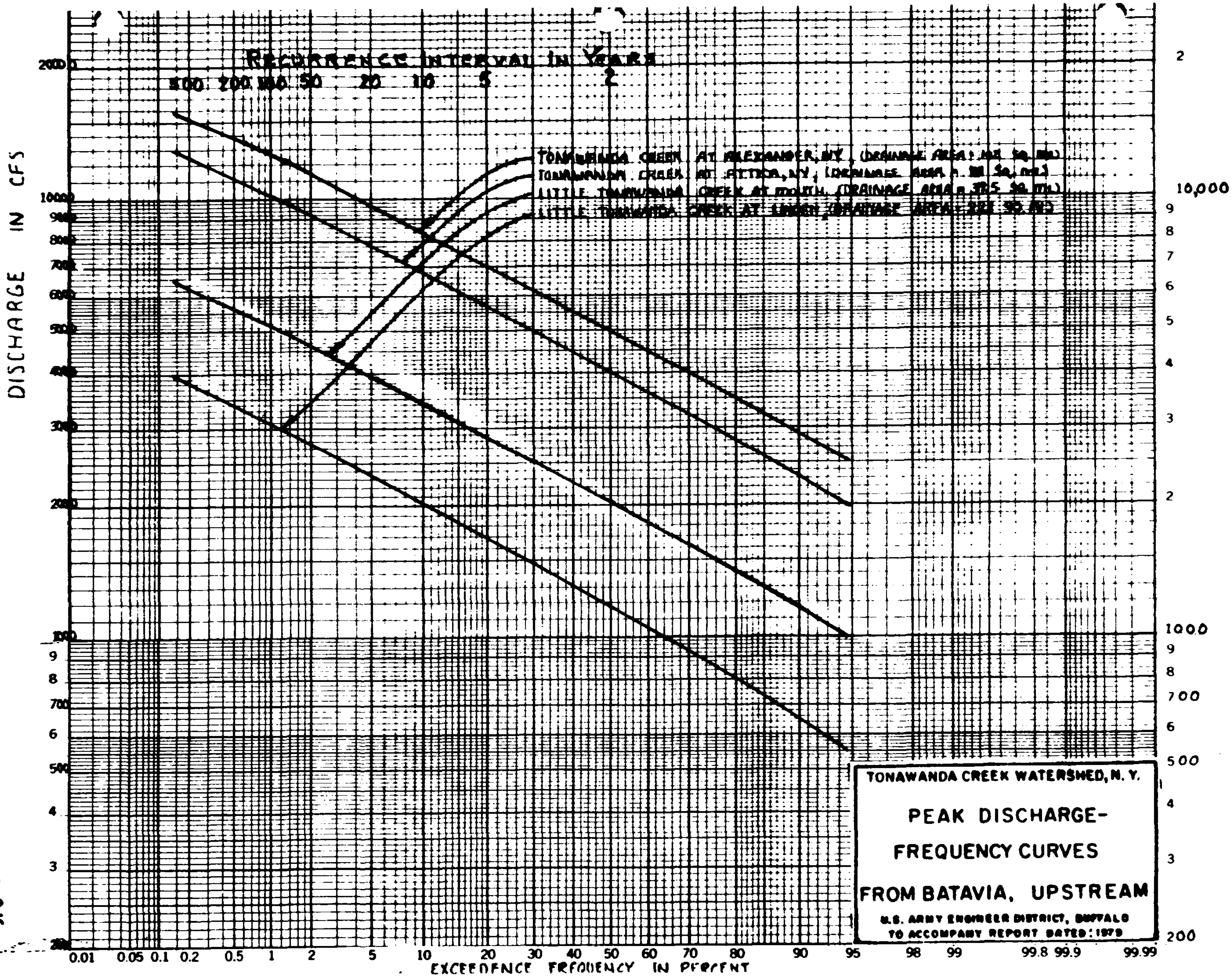
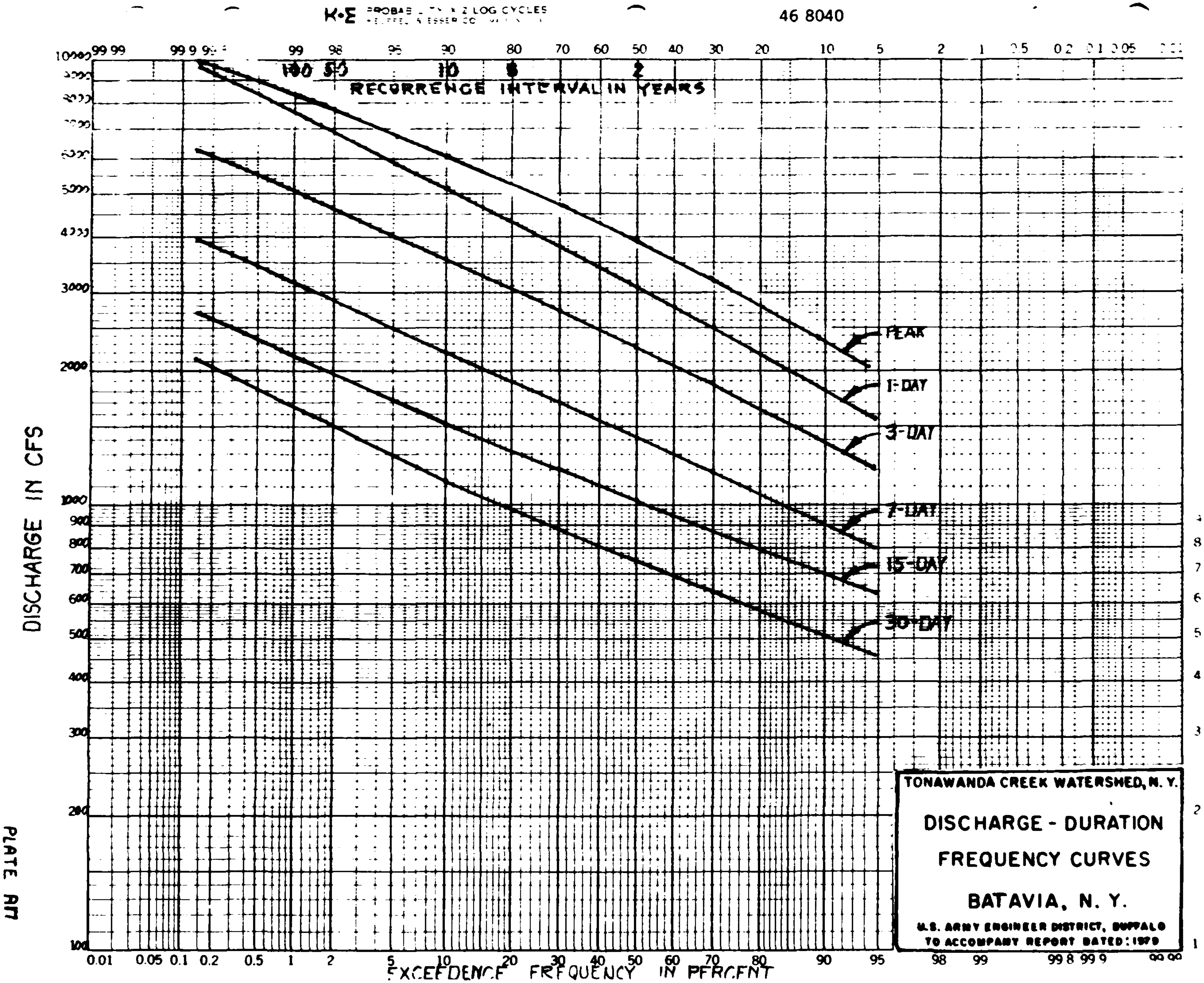
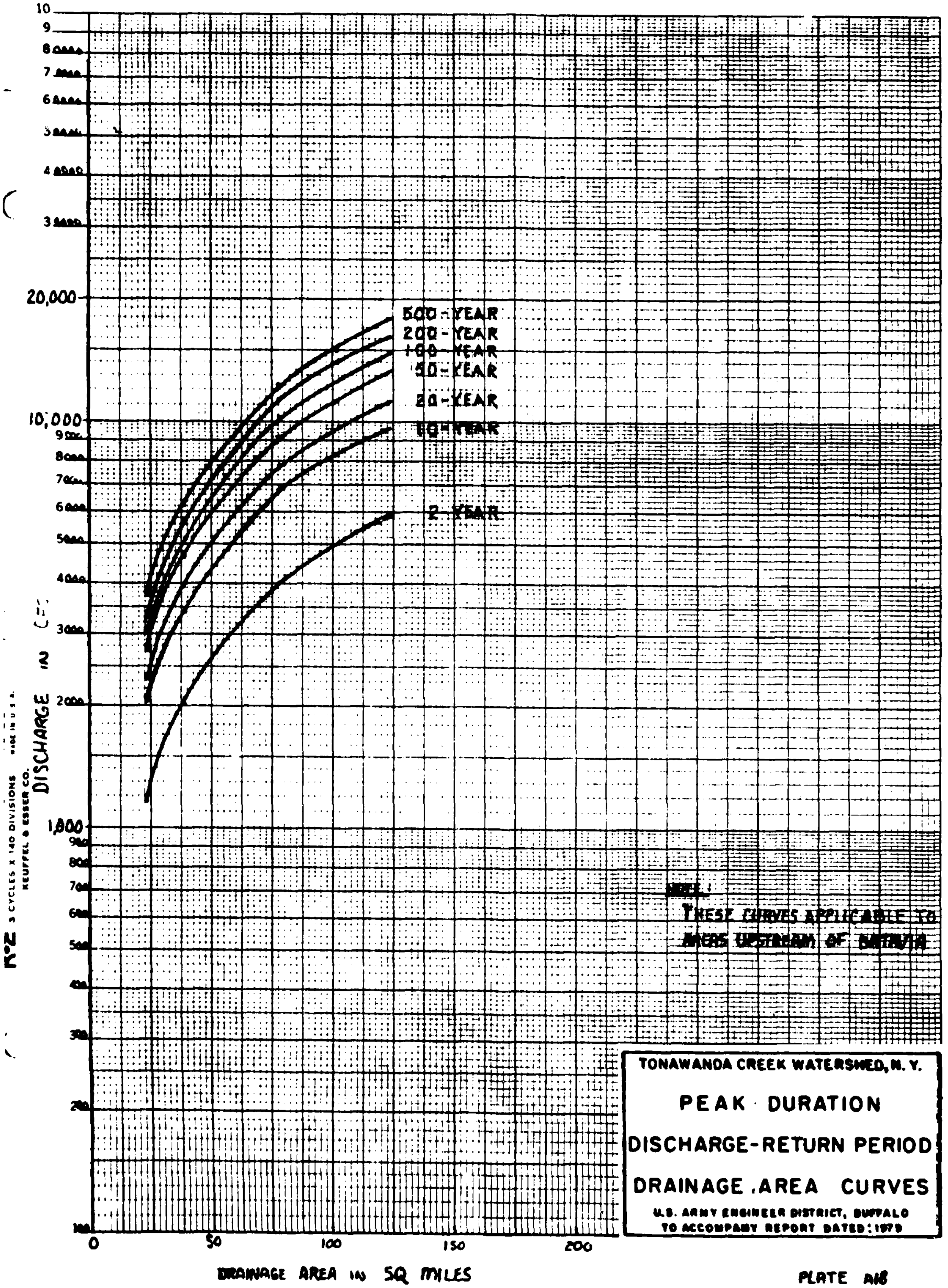

RECURRENCE INTERVAL IN YEARS
500 200 100 50 20 10 5 2
TONAWANDA CREEK AT ALEXANDER, N.Y.
TONAWANDA CREEK AT ATTICA, N.Y.
LITTLE TONAWANDA CREEK AT MOUTH
LITTLE TONAWANDA CREEK AT LINDEN
DISCHARGE IN CFS
EXCEEDENCE FREQUENCY IN PERCENT
TONAWANDA CREEK WATERSHED, N. Y.
PEAK DISCHARGE-
FREQUENCY CURVES
FROM BATAVIA, UPSTREAM
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A16.



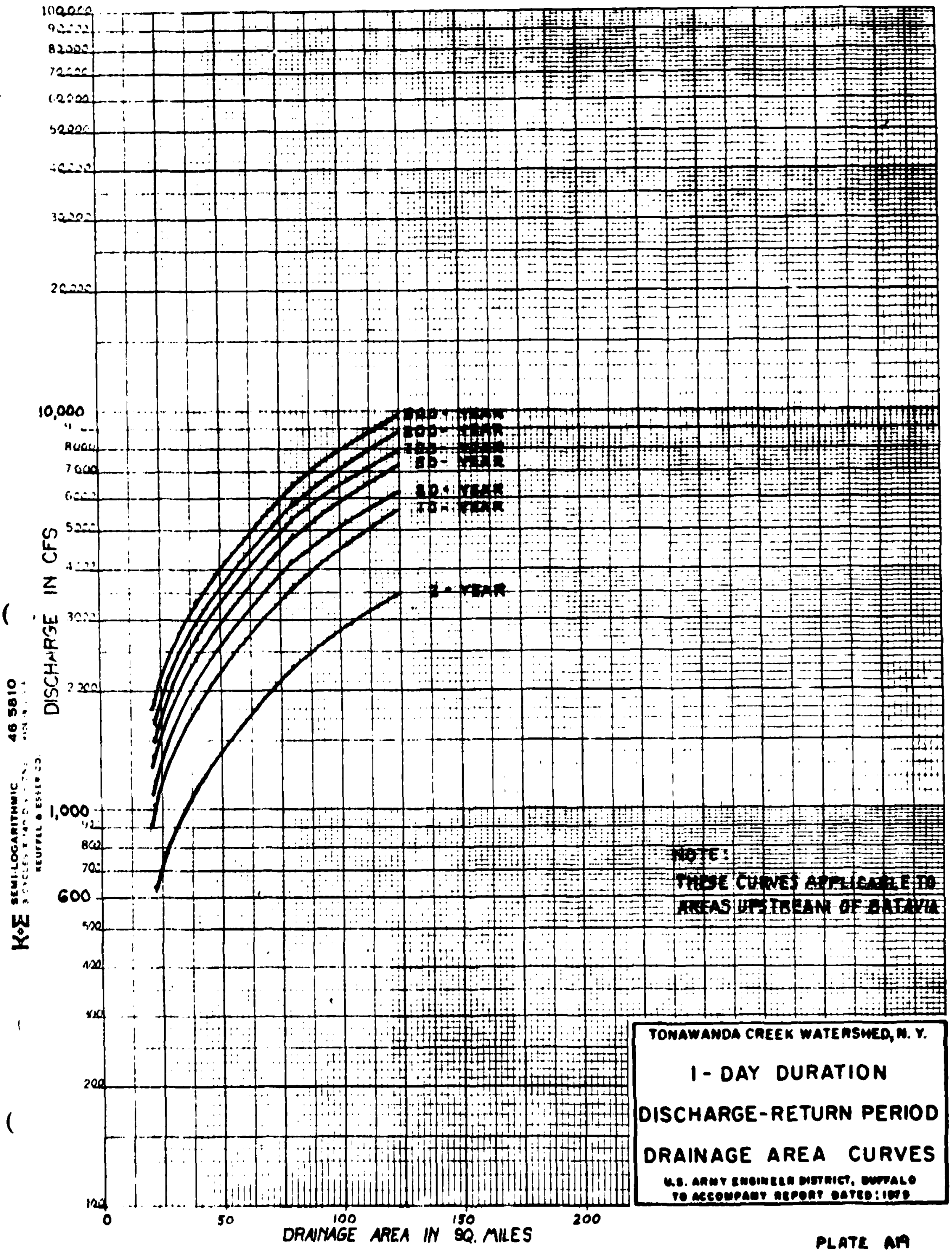
K•E PROBABILITY X 2 LOG CYCLES
46 8040
RECURRENCE INTERVAL IN YEARS
100
50
10
5
2
PEAK
1-DAY
3-DAY
7-DAY
15-DAY
30-DAY
DISCHARGE IN CFS
EXCEEDENCE FREQUENCY IN PERCENT
TONAWANDA CREEK WATERSHED, N. Y.
DISCHARGE - DURATION
FREQUENCY CURVES
BATAVIA, N. Y.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A17



500-YEAR
200-YEAR
100-YEAR
50-YEAR
20-YEAR
10-YEAR
2-YEAR
20,000
10,000
1,000
DISCHARGE IN CFS
DRAINAGE AREA IN SQ MILES
0
50
100
150
200
NOTE:
THESE CURVES APPLICABLE TO AREAS UPSTREAM OF BATAVIA
TONAWANDA CREEK WATERSHED, N. Y.
PEAK DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.

PLATE A18



TONAWANDA CREEK WATERSHED, N. Y.

1-DAY DURATION

DISCHARGE-RETURN PERIOD

DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A19

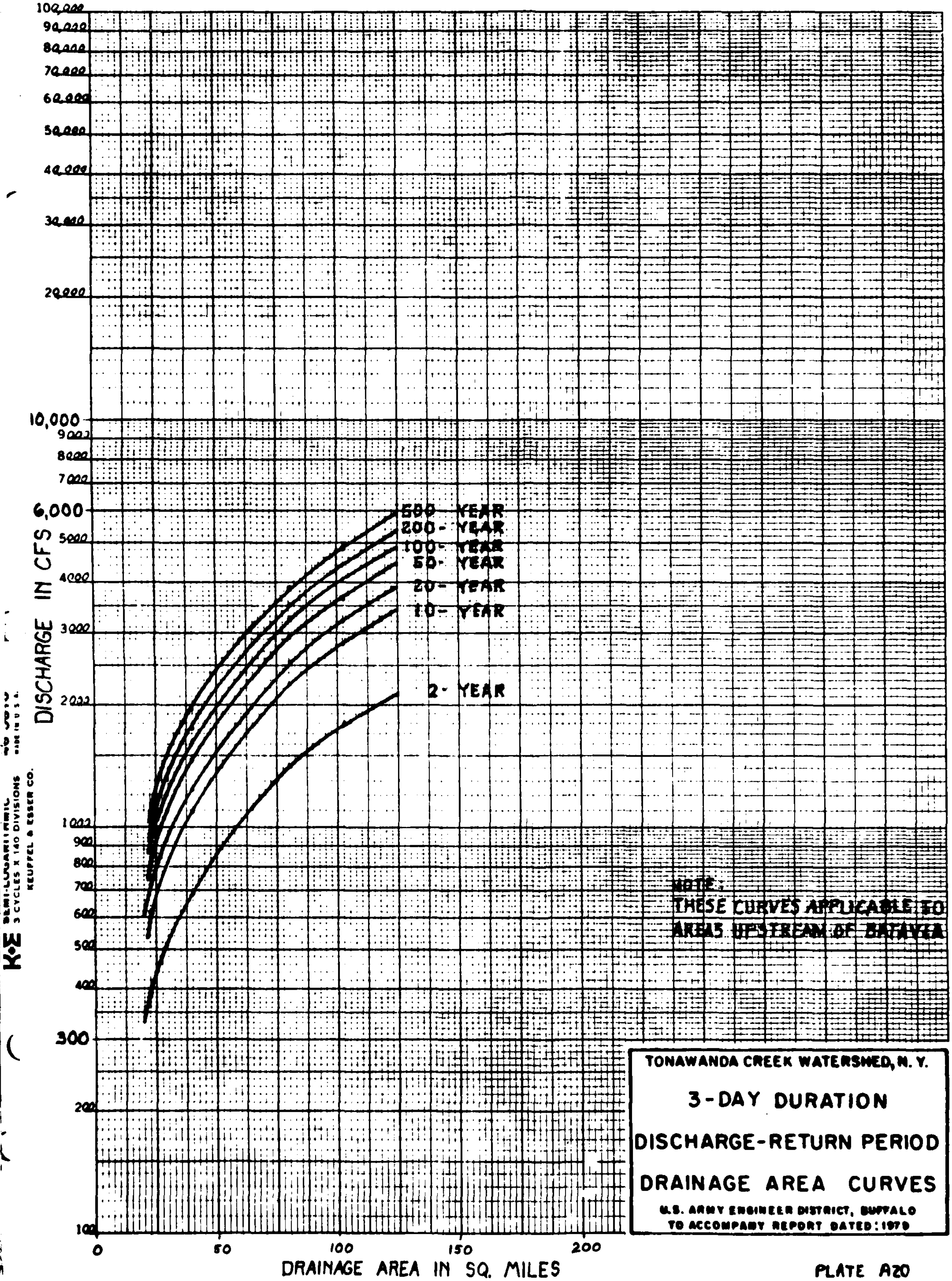
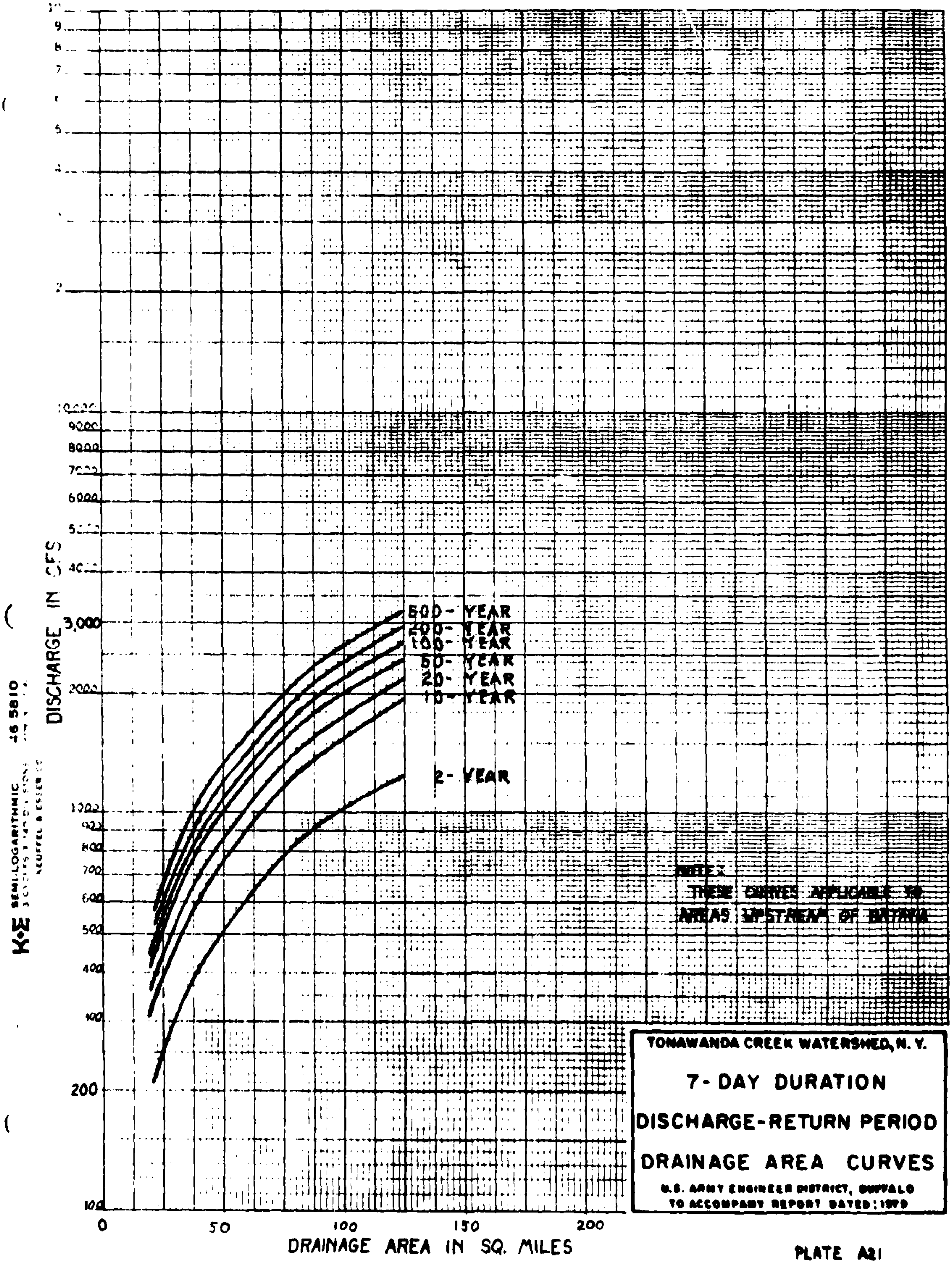

100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
9000
8000
7000
6,000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
DISCHARGE IN CFS
0
50
100
150
200
DRAINAGE AREA IN SQ. MILES
500 - YEAR
200 - YEAR
100 - YEAR
50 - YEAR
20 - YEAR
10 - YEAR
2 - YEAR
NOTE:
THESE CURVES APPLICABLE TO
AREAS UPSTREAM OF BATAVIA
TONAWANDA CREEK WATERSHED, N. Y.
3-DAY DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
K+E SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.

PLATE A20



TONAWANDA CREEK WATERSHED, N. Y.

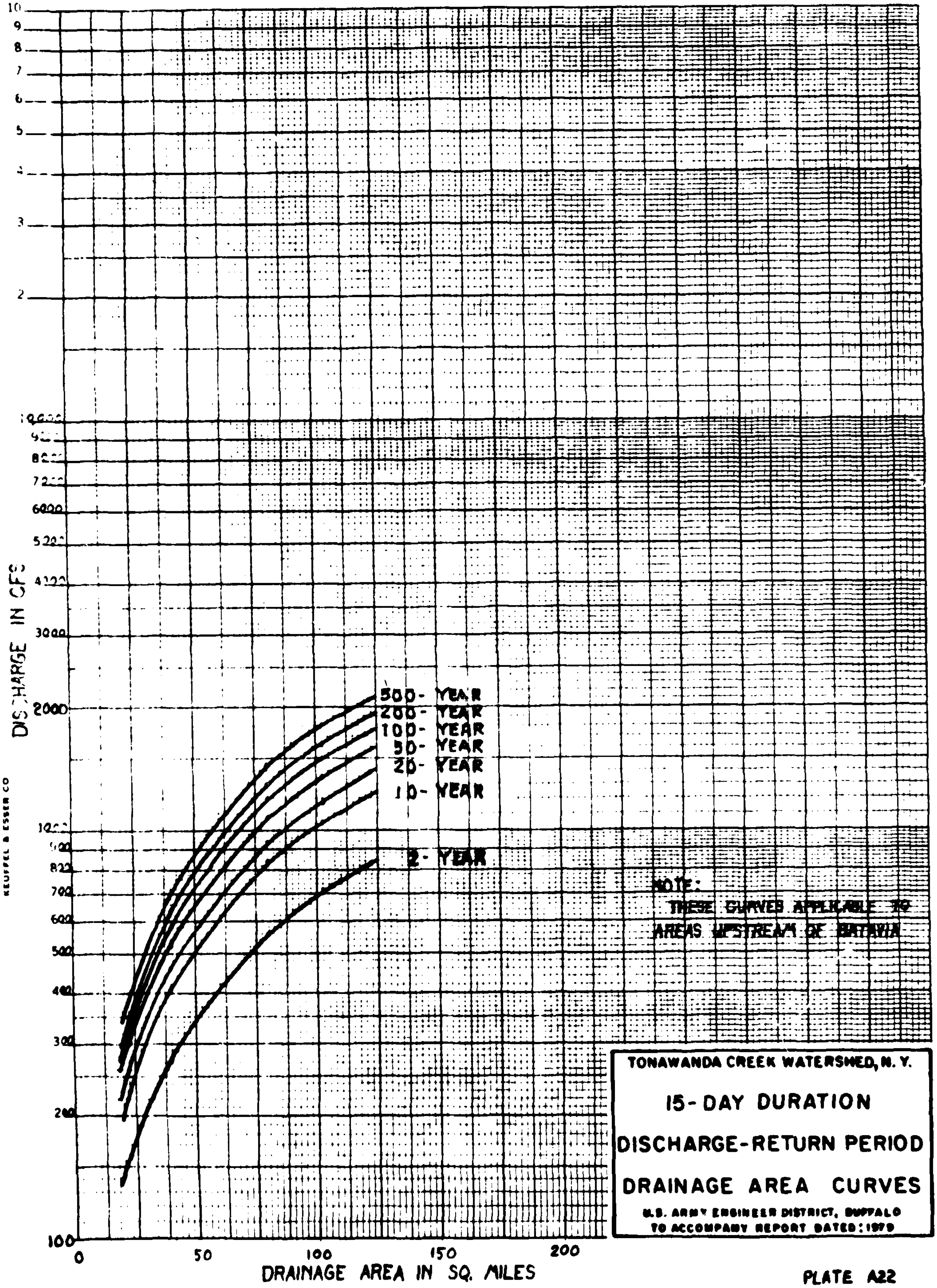
7- DAY DURATION

DISCHARGE-RETURN PERIOD

DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A21



DISCHARGE IN CFS
DRAINAGE AREA IN SQ. MILES
0
50
100
150
200
100
3000
2000
6000
500- YEAR
200- YEAR
100- YEAR
50- YEAR
20- YEAR
10- YEAR
2- YEAR
NOTE:
THESE CURVES APPLICABLE TO
AREAS UPSTREAM OF BATAVIA
TONAWANDA CREEK WATERSHED, N. Y.
15-DAY DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
K+E SEMI-LOGARITHMIC
KEUFFEL & ESSER CO

PLATE A22

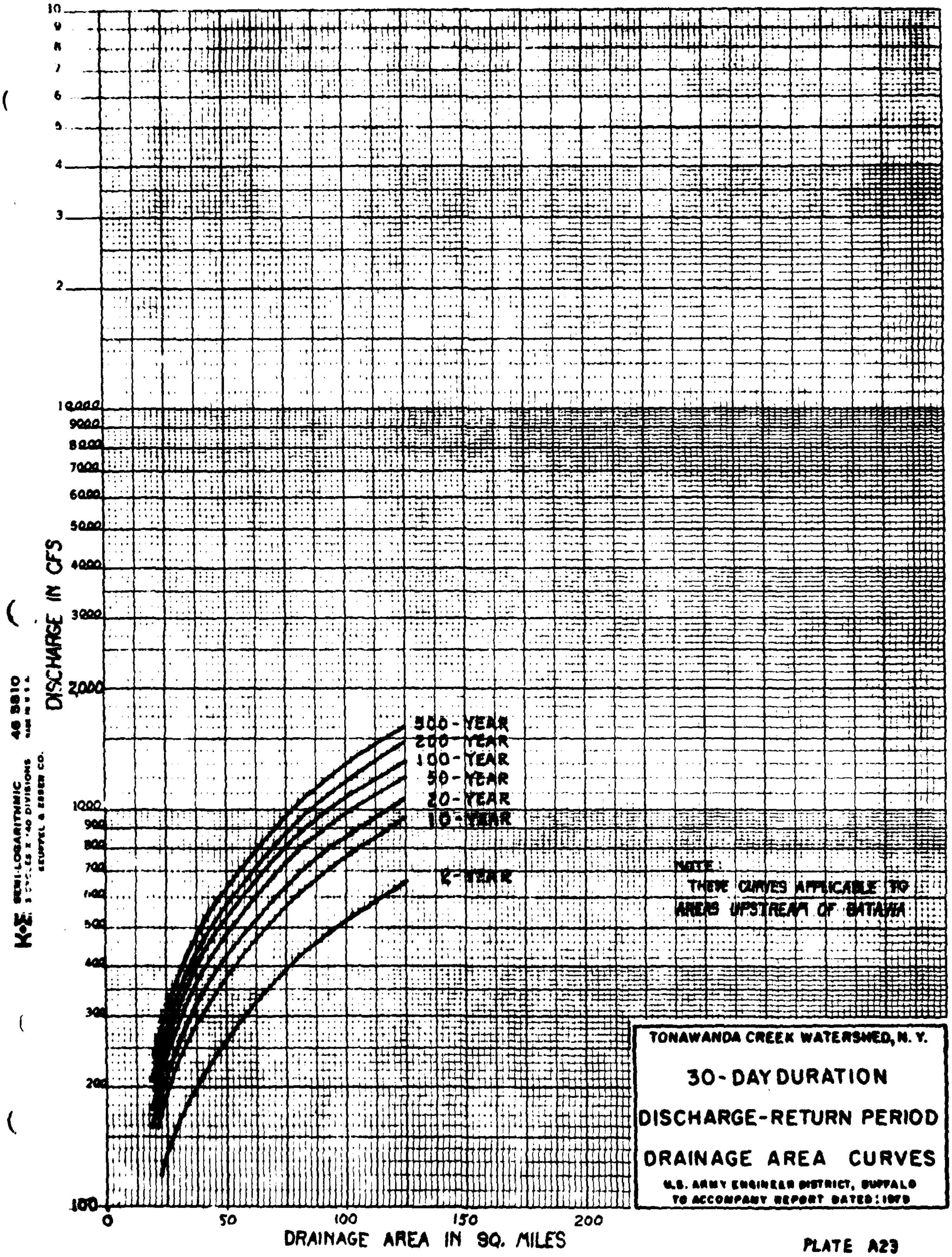
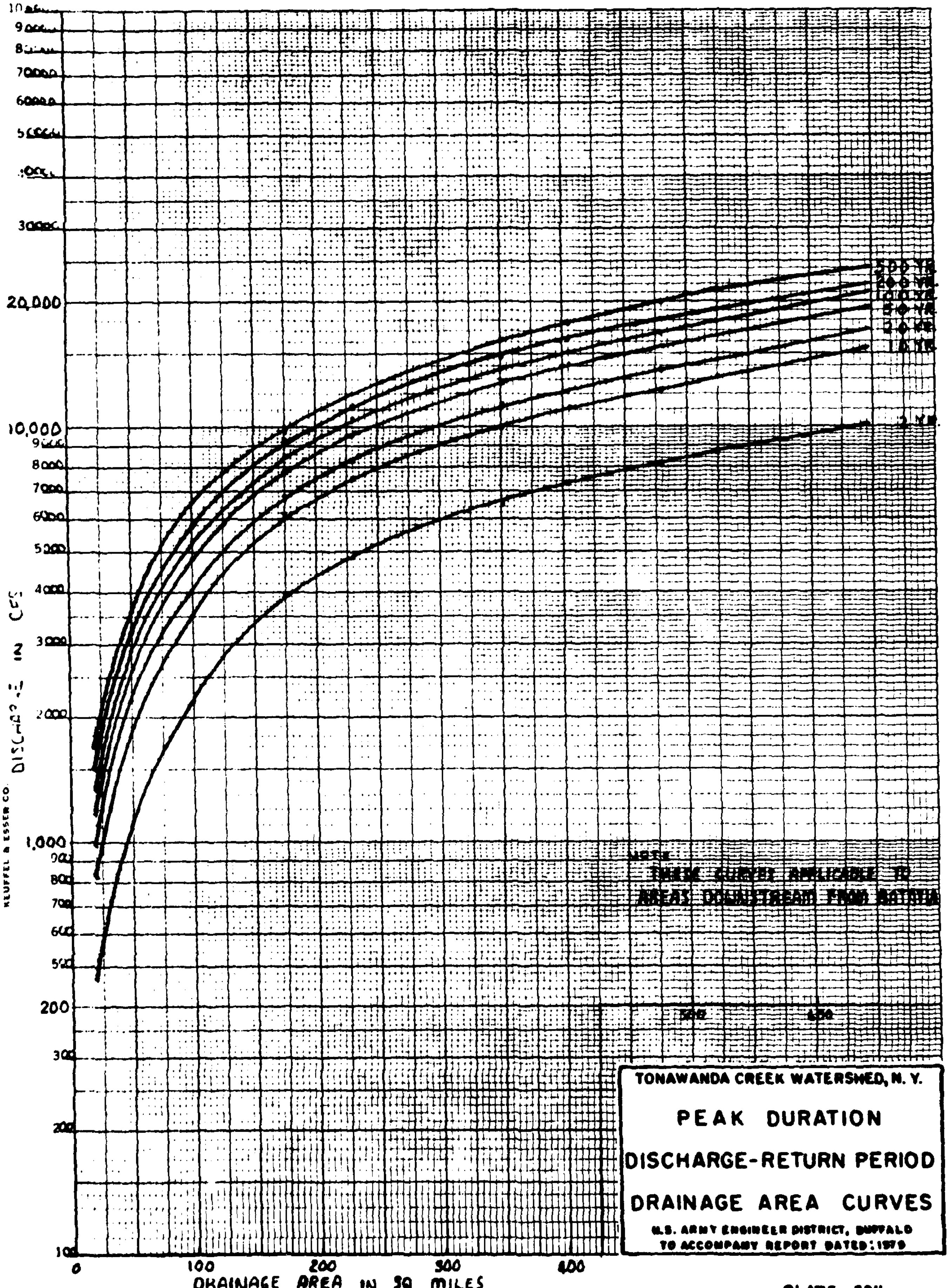

DISCHARGE IN CFS
500-YEAR
200-YEAR
100-YEAR
50-YEAR
20-YEAR
10-YEAR
2-YEAR
NOTE:
THESE CURVES APPLICABLE TO
AREAS UPSTREAM OF BATAVIA
DRAINAGE AREA IN SQ. MILES
TONAWANDA CREEK WATERSHED, N. Y.
30-DAY DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A23



20,000
10,000
8000
7000
6000
5000
4000
3000
2000
1,000
DISCHARGE IN CFS
0
100
200
300
400
DRAINAGE AREA IN SQ MILES
500 YR.
200 YR.
100 YR.
50 YR.
20 YR.
10 YR.
2 YR.
NOTE
THESE CURVES APPLICABLE TO
AREAS DOWNSTREAM FROM BATAVIA
TONAWANDA CREEK WATERSHED, N. Y.
PEAK DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

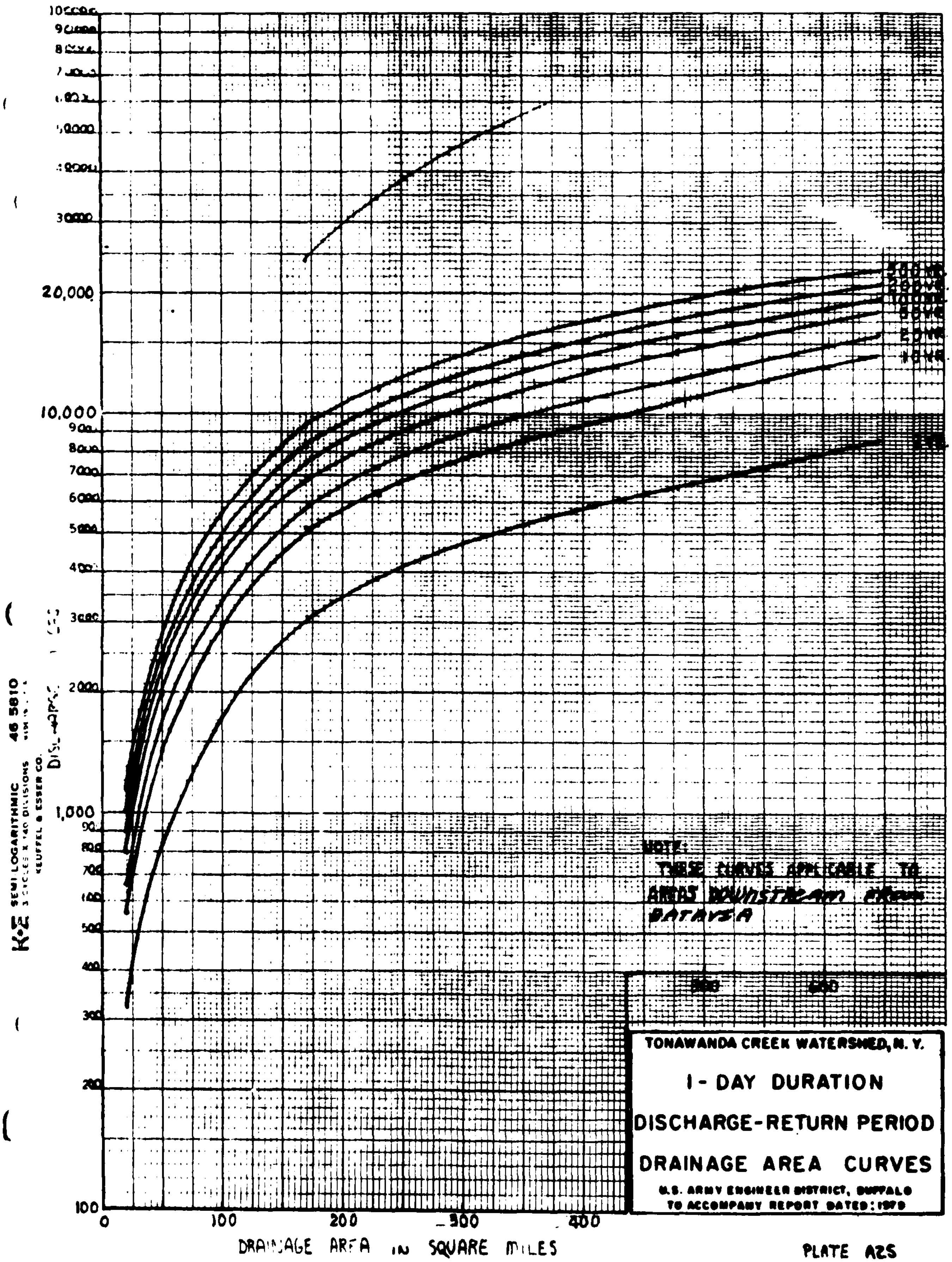
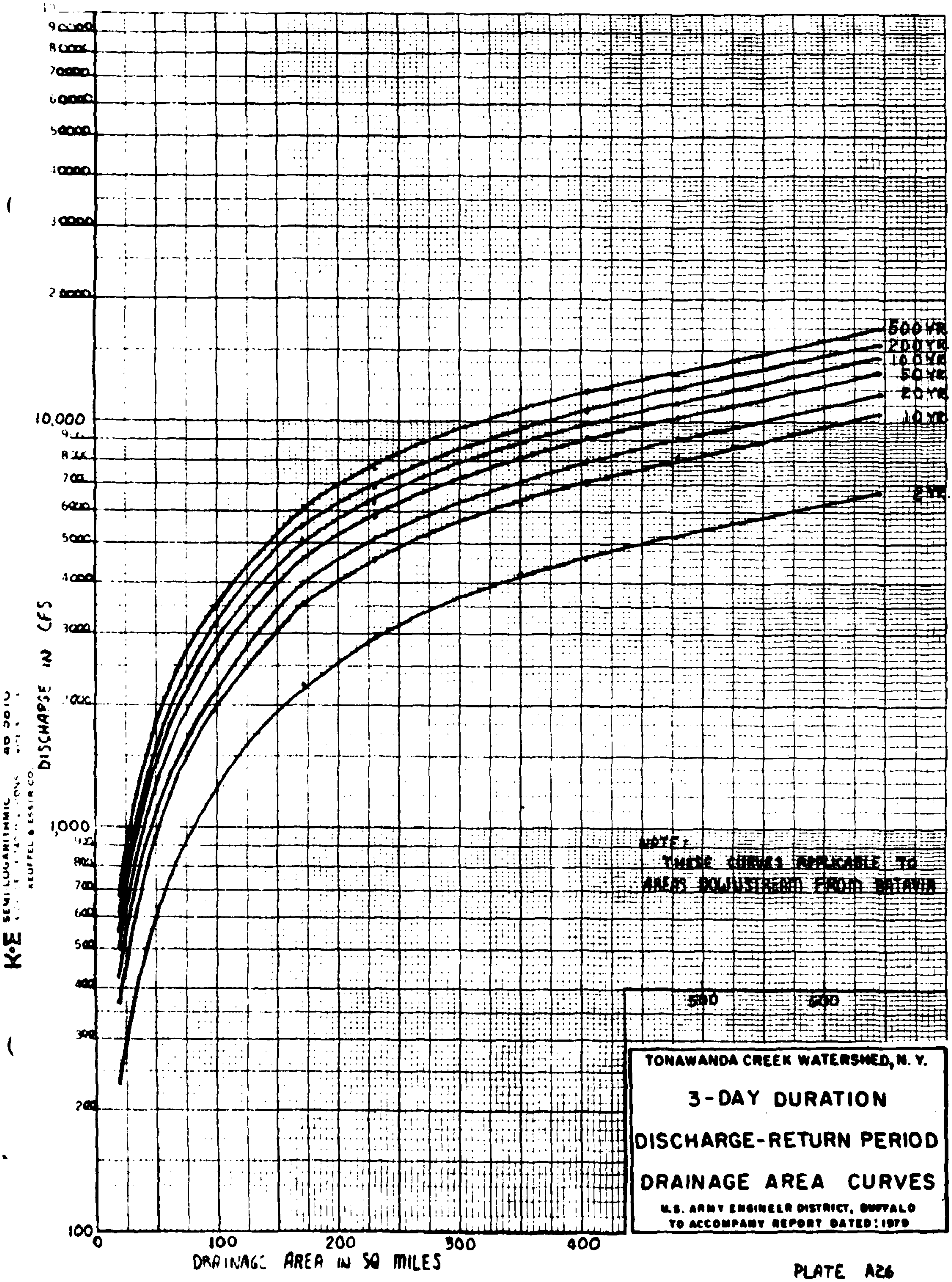

10,000
20,000
30,000
1,000
100
0
100
200
300
400
500
600
DRAINAGE AREA IN SQUARE MILES
NOTE:
THESE CURVES APPLICABLE TO AREAS DOWNSTREAM FROM BATAVIA
KEUFFEL & ESSER CO.
SEMI-LOGARITHMIC 46 5810
TONAWANDA CREEK WATERSHED, N. Y.
1 - DAY DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A25



TONAWANDA CREEK WATERSHED, N. Y.

3-DAY DURATION

DISCHARGE-RETURN PERIOD

DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A26

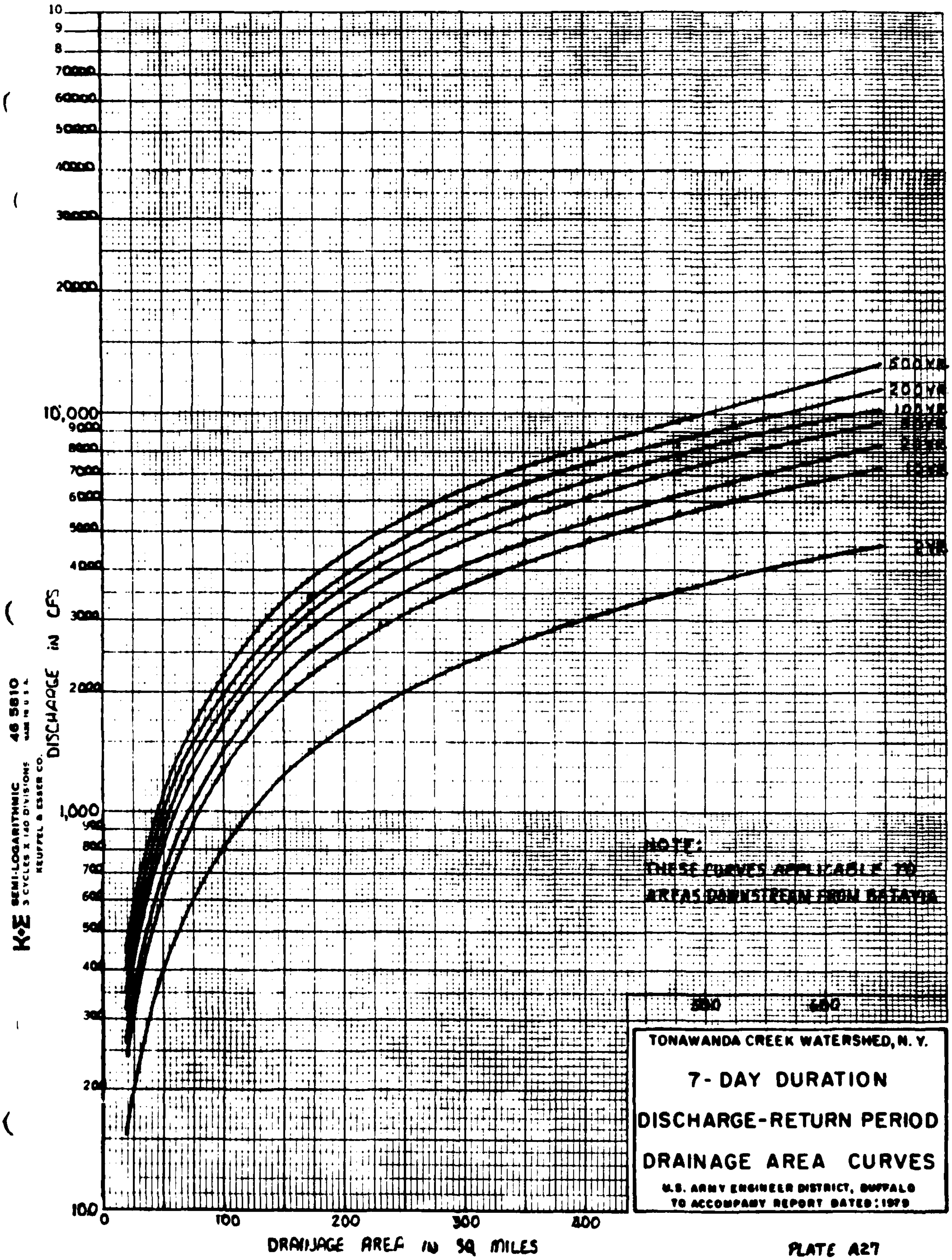
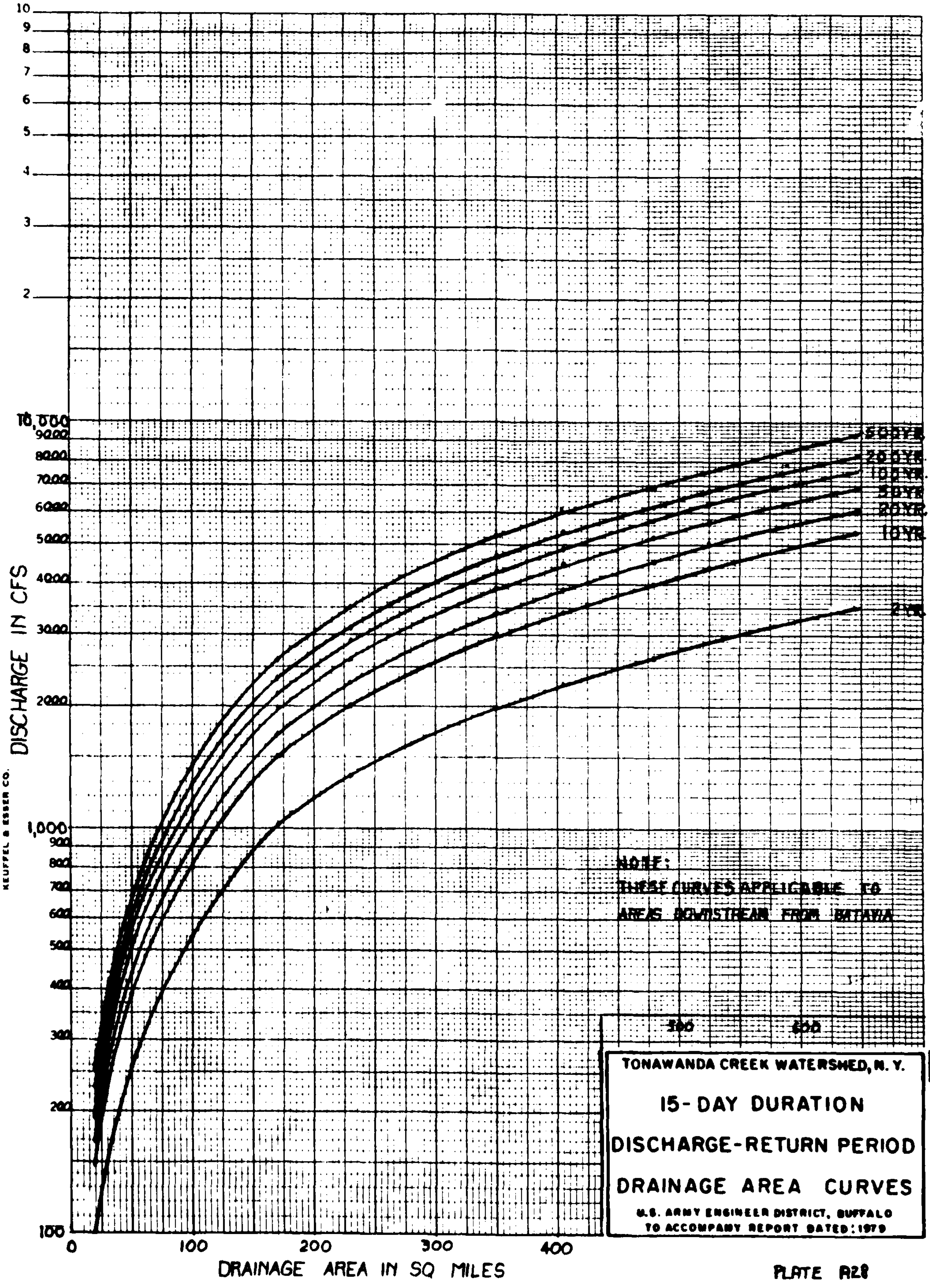

DISCHARGE IN CFS
10,000
1,000
100
0
100
200
300
400
DRAINAGE AREA IN SQ MILES
500 YR
200 YR
100 YR
2 YR
NOTE:
THESE CURVES APPLICABLE TO
AREAS DOWNSTREAM FROM BATAVIA
TONAWANDA CREEK WATERSHED, N. Y.
7-DAY DURATION
DISCHARGE-RETURN PERIOD
DRAINAGE AREA CURVES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
K+E SEMI-LOGARITHMIC 46 5810
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.

PLATE A27



TONAWANDA CREEK WATERSHED, N. Y.

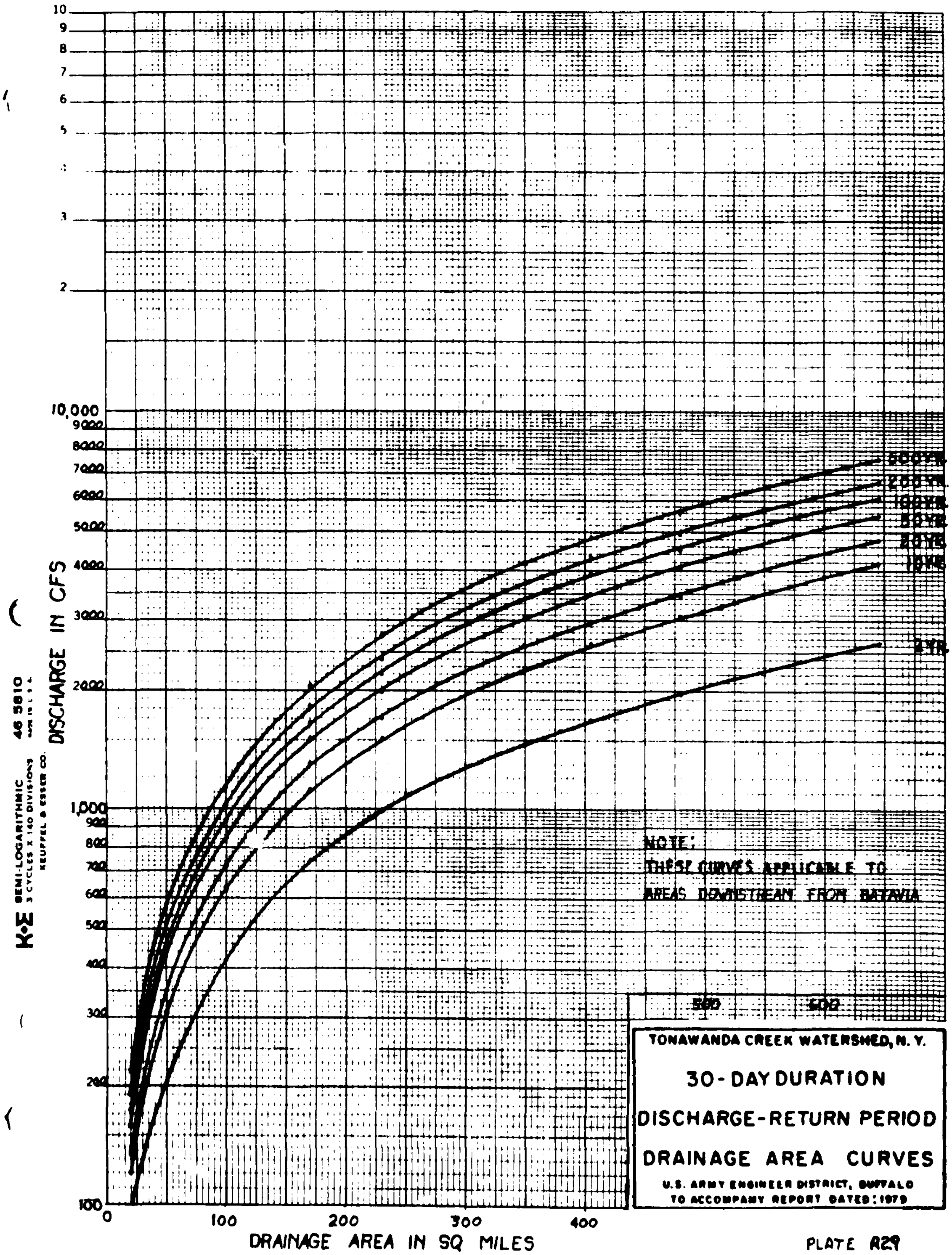
15-DAY DURATION

DISCHARGE-RETURN PERIOD

DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A28



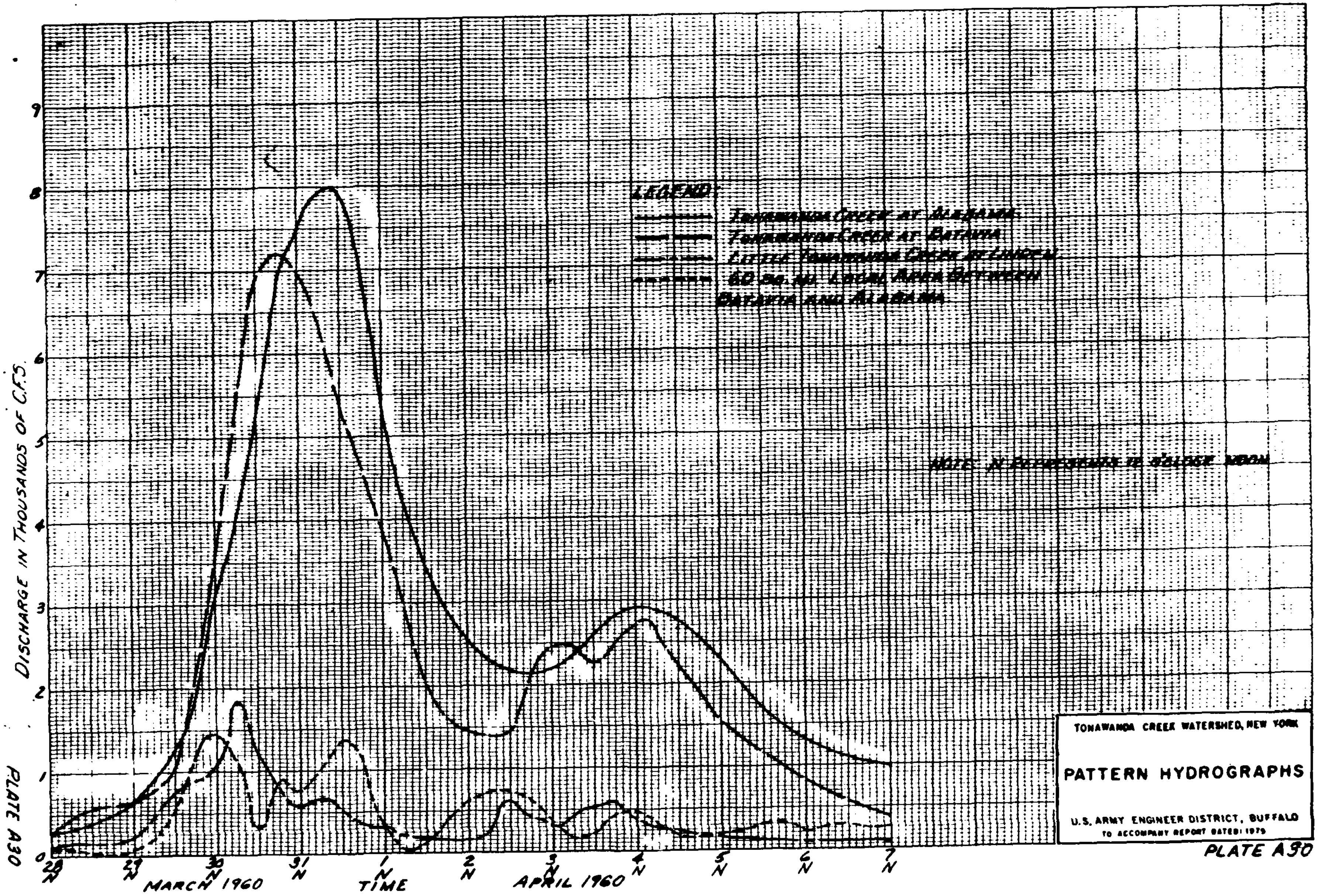
TONAWANDA CREEK WATERSHED, N. Y.

30-DAY DURATION

DISCHARGE-RETURN PERIOD

DRAINAGE AREA CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

PATTERN HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1975

PLATE A30

PLATE A30

K•E 10 X 12 TO THE INCH KEUFFEL & ESSER CO.

46 1930

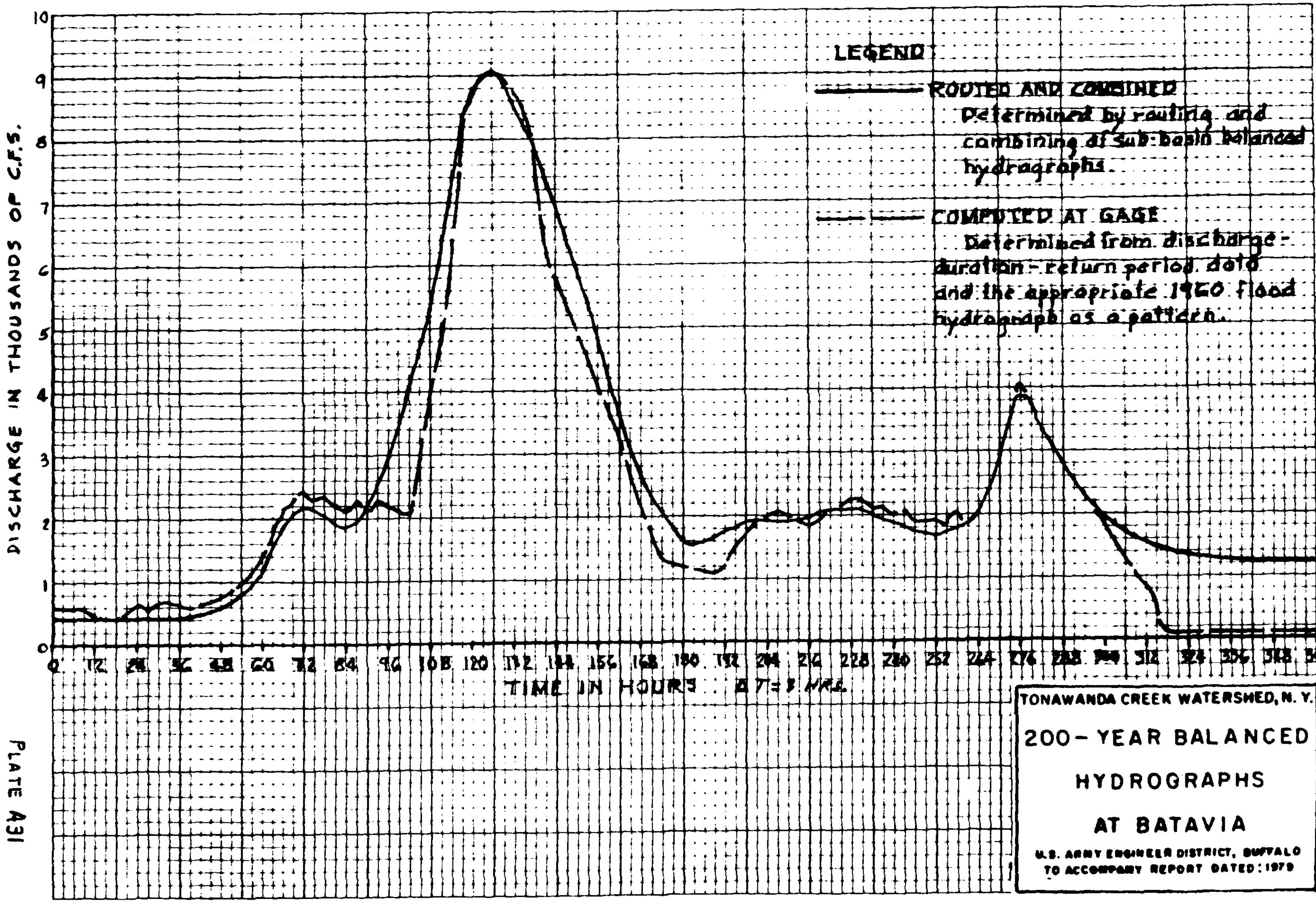
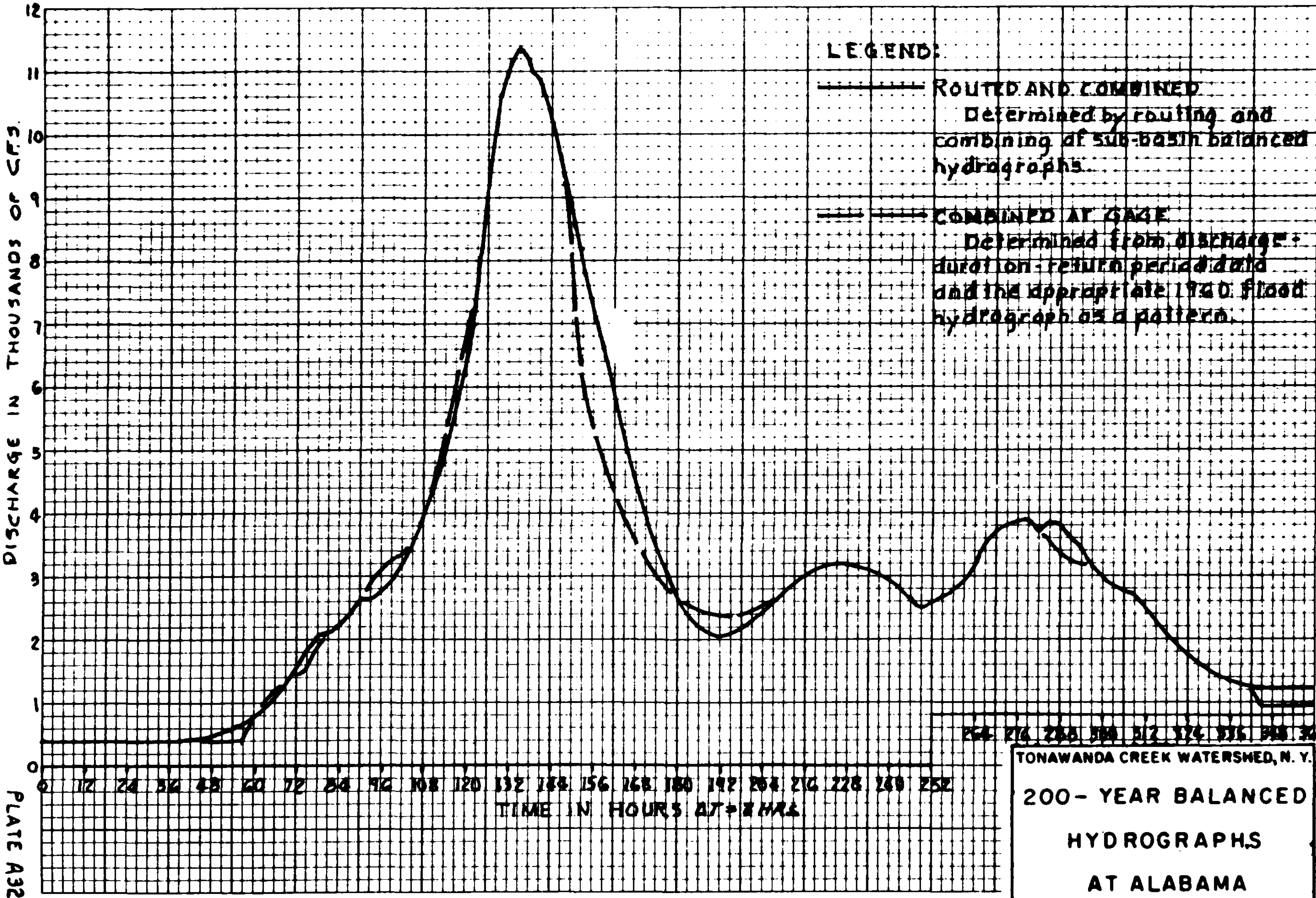


PLATE A31

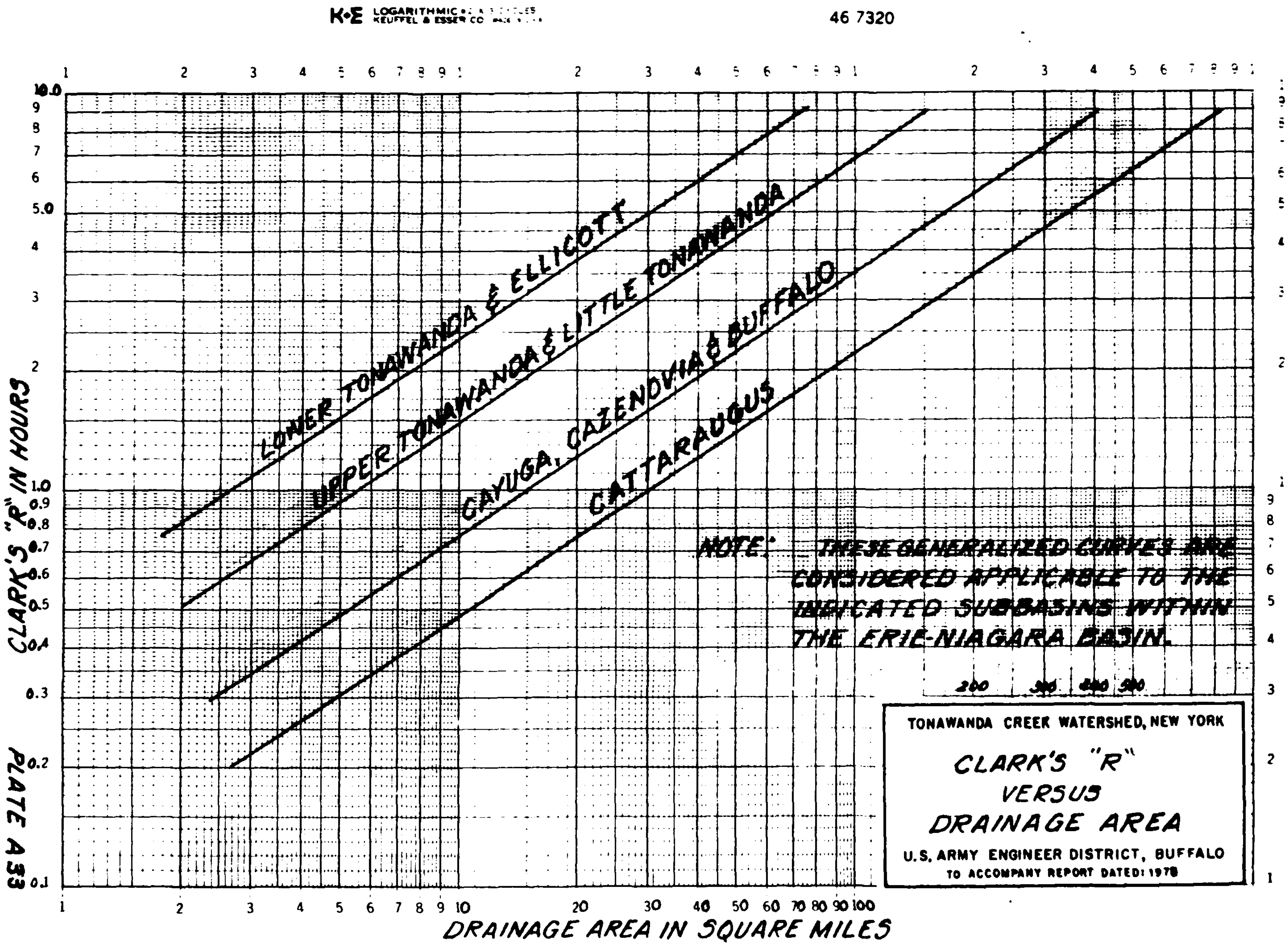


TONAWANDA CREEK WATERSHED, N. Y.

200- YEAR BALANCED HYDROGRAPHS AT ALABAMA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A32

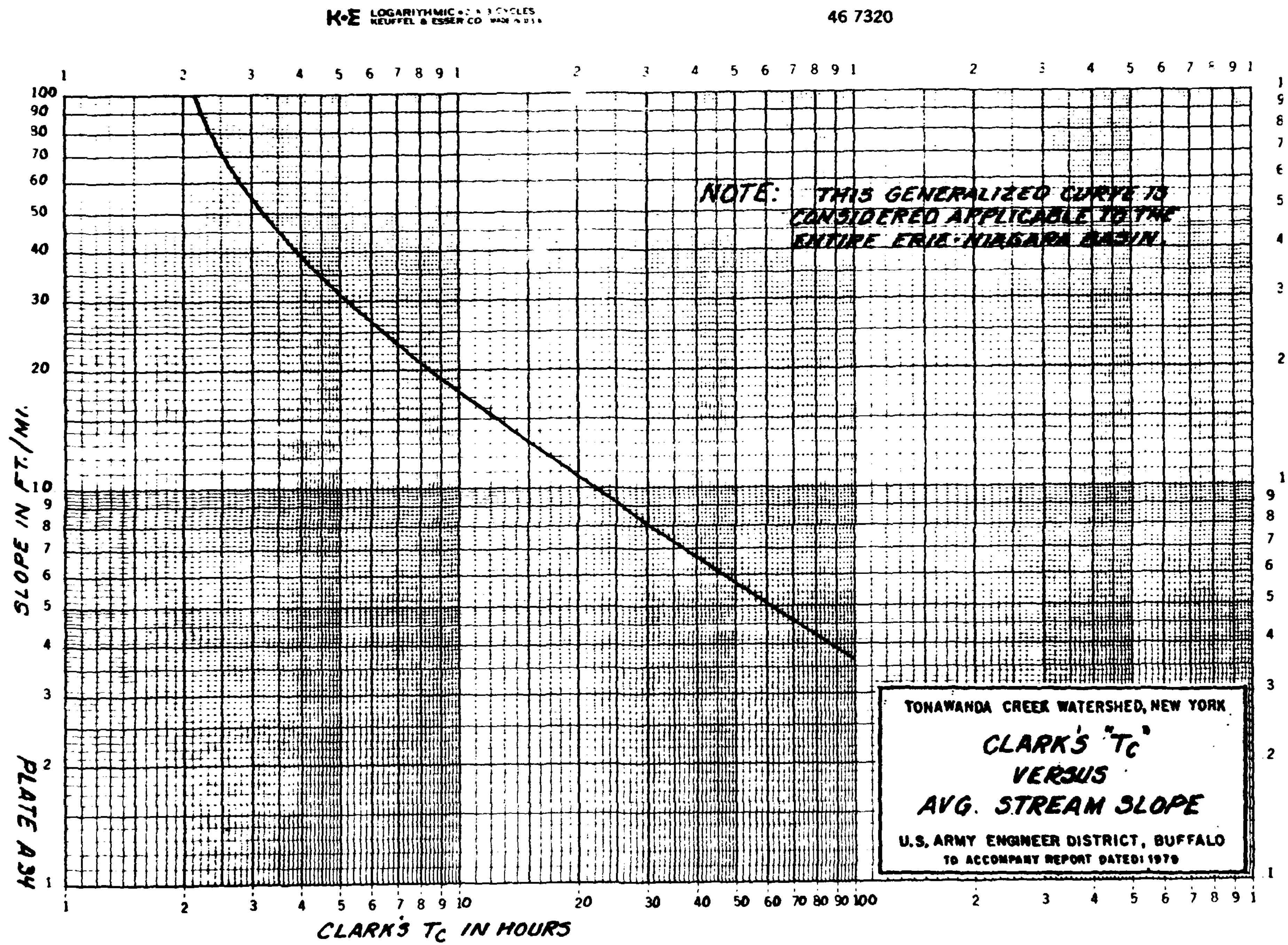


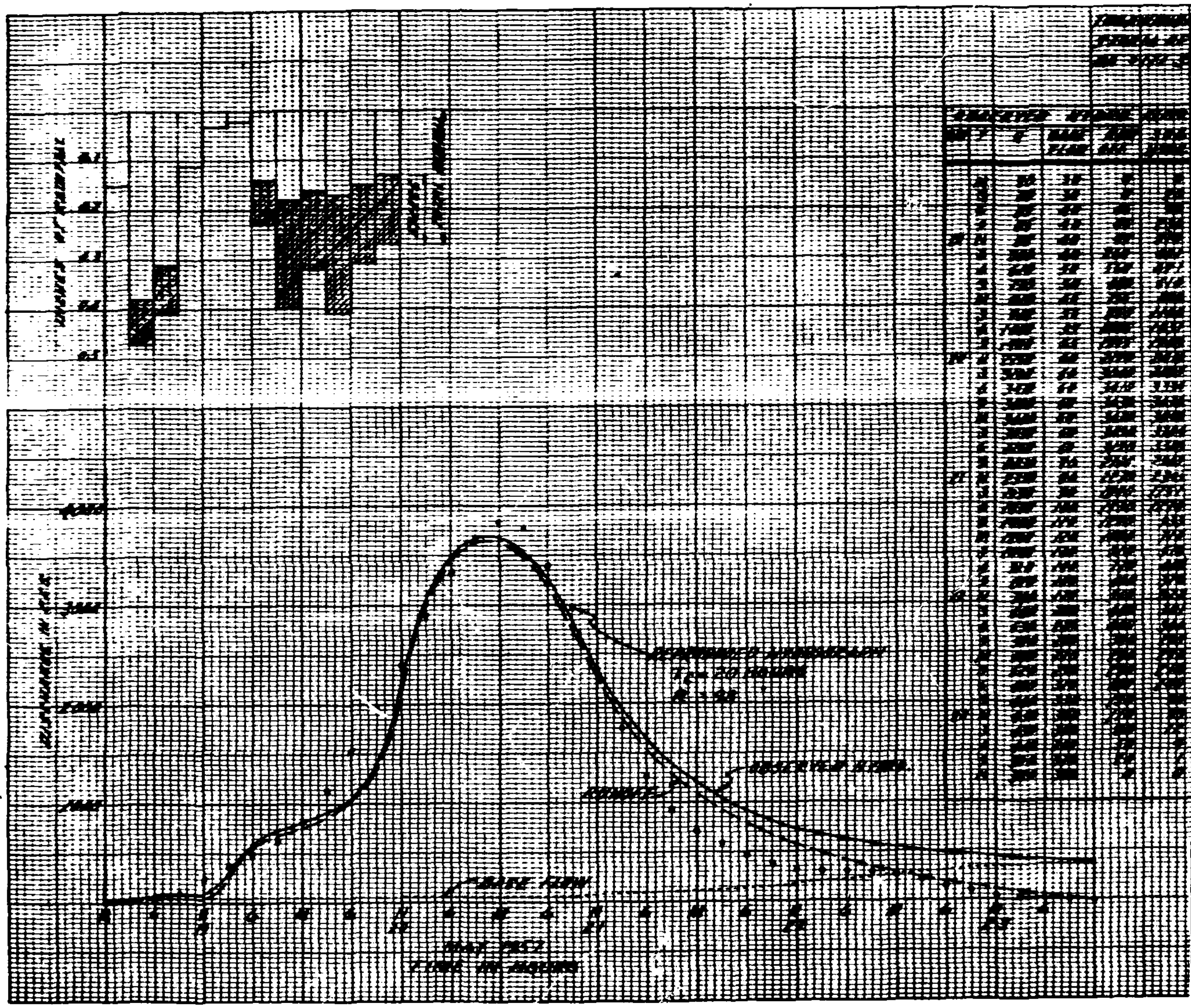
TONAWANDA CREEK WATERSHED, NEW YORK

CLARK'S "R"
VERSUS
DRAINAGE AREA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1978

PLATE A33


K·E LOGARITHMIC 3 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7320
NOTE: THIS GENERALIZED CURVE IS CONSIDERED APPLICABLE TO THE ENTIRE ERIE-NIAGARA BASIN.
TONAWANDA CREEK WATERSHED, NEW YORK
CLARK'S "Tc"
VERSUS
AVG. STREAM SLOPE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
SLOPE IN FT./MI.
CLARK'S Tc IN HOURS
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100



TONAWANDA CREEK WATERSHED, NEW YORK

HYDROGRAPHS AT BATAVIA

FOR 19-20 MAY 1957 STORM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1970

PLATE A35

PLATE A36

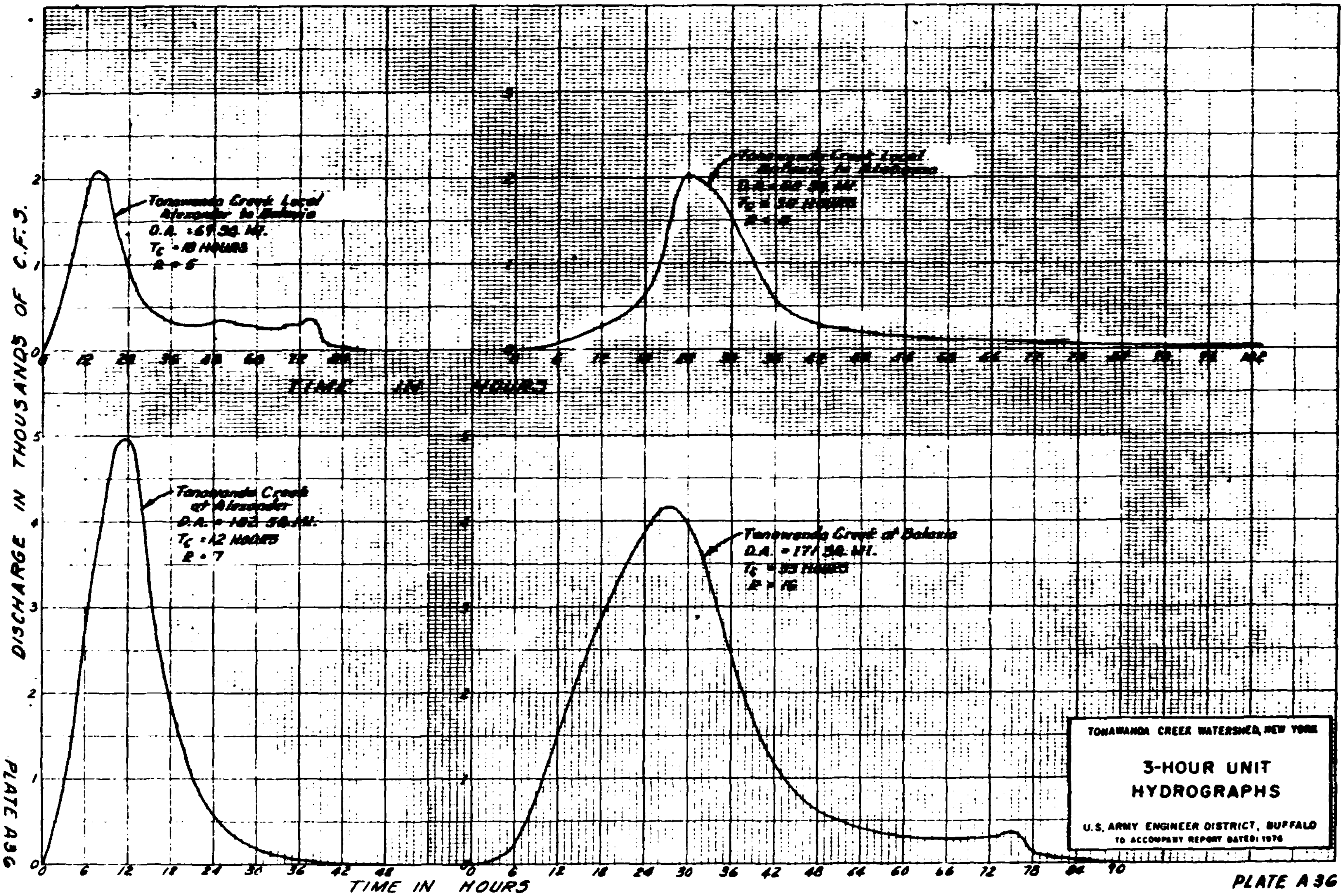
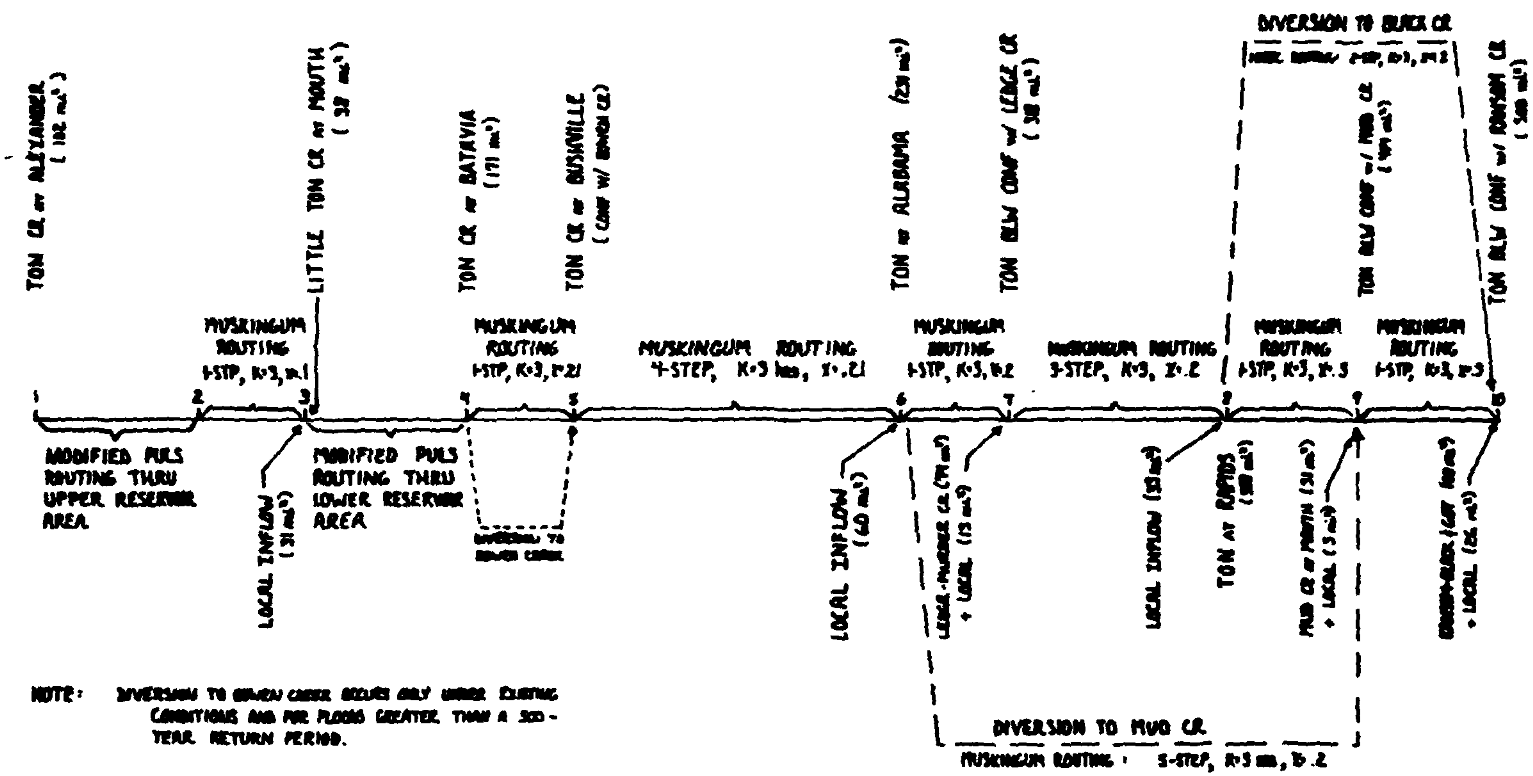


PLATE A36

PLATE A36

TONAWANDA CREEK ROUTING SCHEMATIC



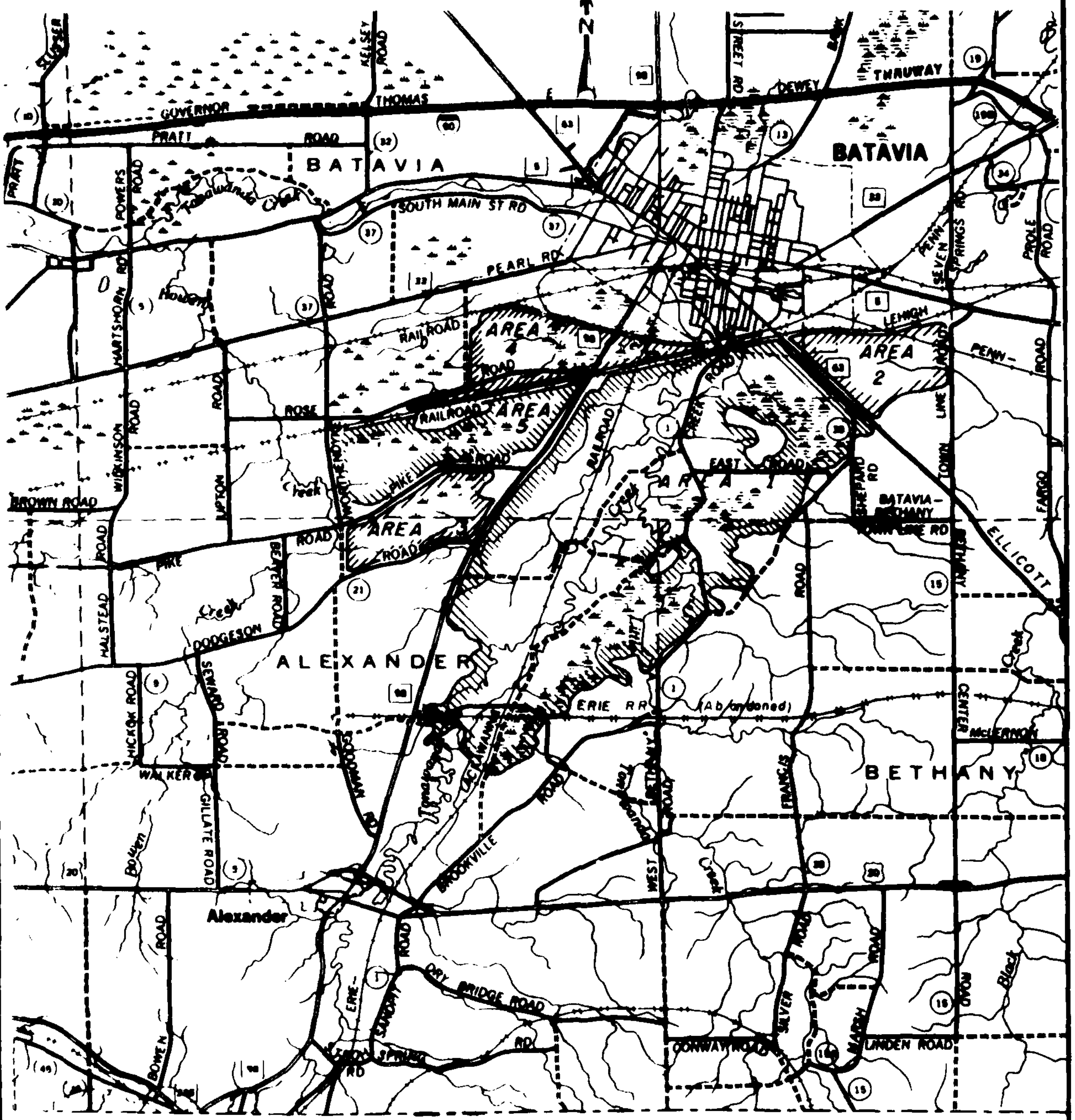
NOTE: DIVERSION TO BOWEN CREEK OCCURS ONLY UNDER EXISTING CONDITIONS AND FOR FLOODS GREATER THAN A 500-YEAR RETURN PERIOD.

PLATE A37

TONAWANDA CREEK WATERSHED, N. Y.

ROUTING SCHEMATIC

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



SCALE IN MILES

1 0 1 2 3 4

NOTE:

See paragraph A 1.35 for explanation.

TONAWANDA CREEK WATERSHED, N.Y.

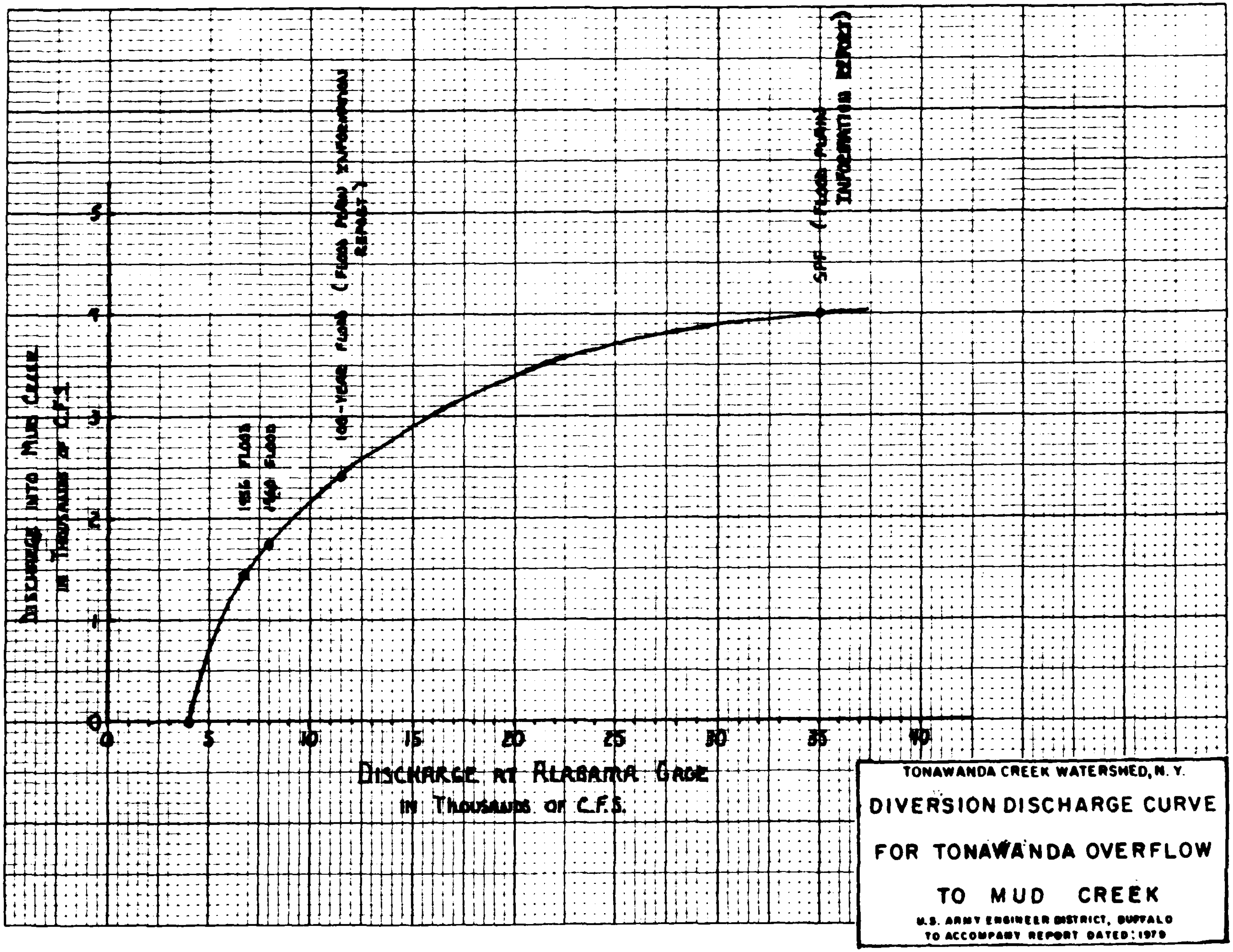
EXISTING CONDITIONS

FLOODED AREAS UPSTREAM OF BATAVIA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A38

K+E 10 X 10 TO 1/2 INCH KEUFFEL & ESSER CO. 46 1020



TONAWANDA CREEK WATERSHED, N. Y.

DIVERSION DISCHARGE CURVE

FOR TONAWANDA OVERFLOW

TO MUD CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

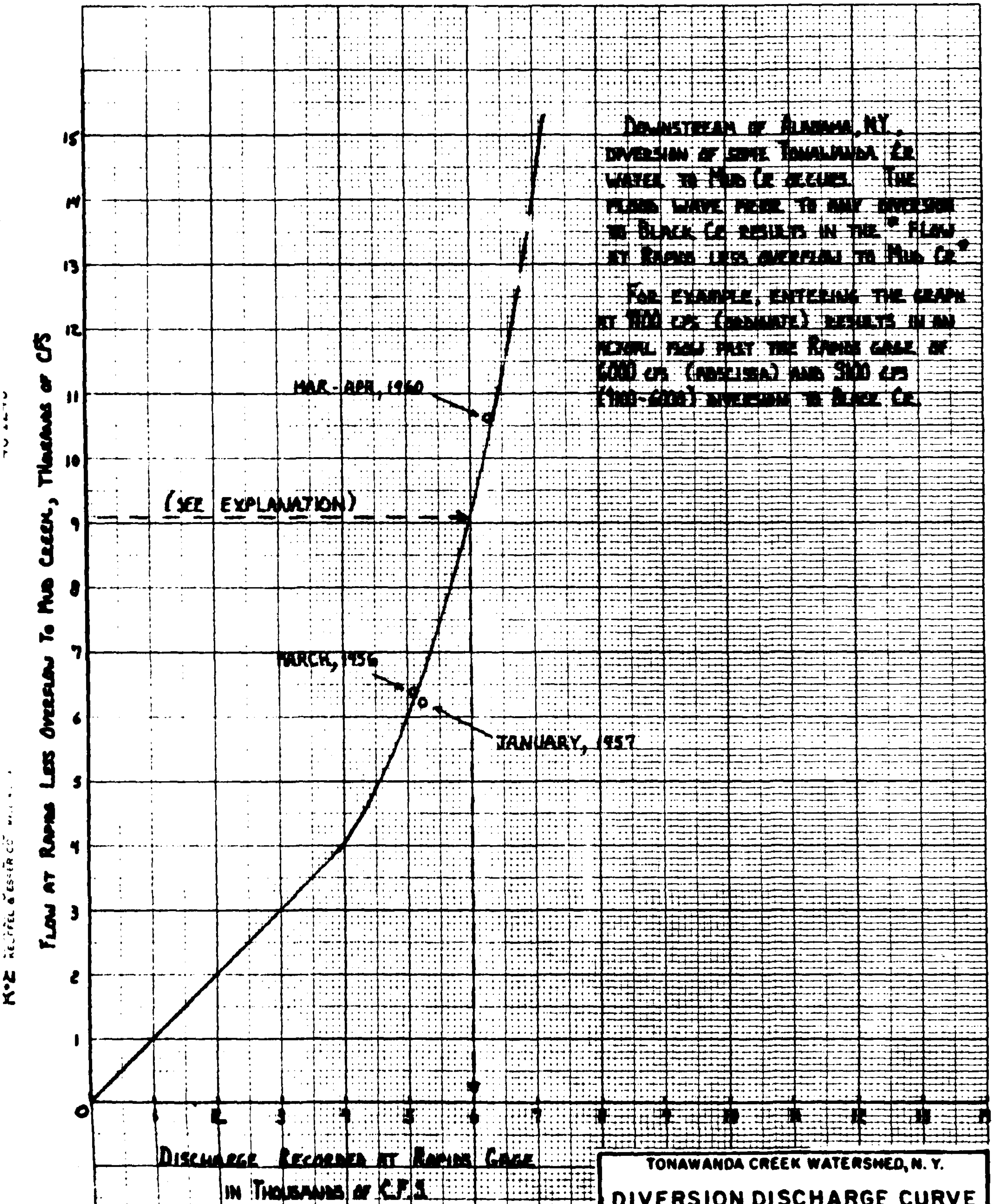


PLATE A41

TONAWANDA CREEK WATERSHED, N. Y.

DIVERSION DISCHARGE CURVE

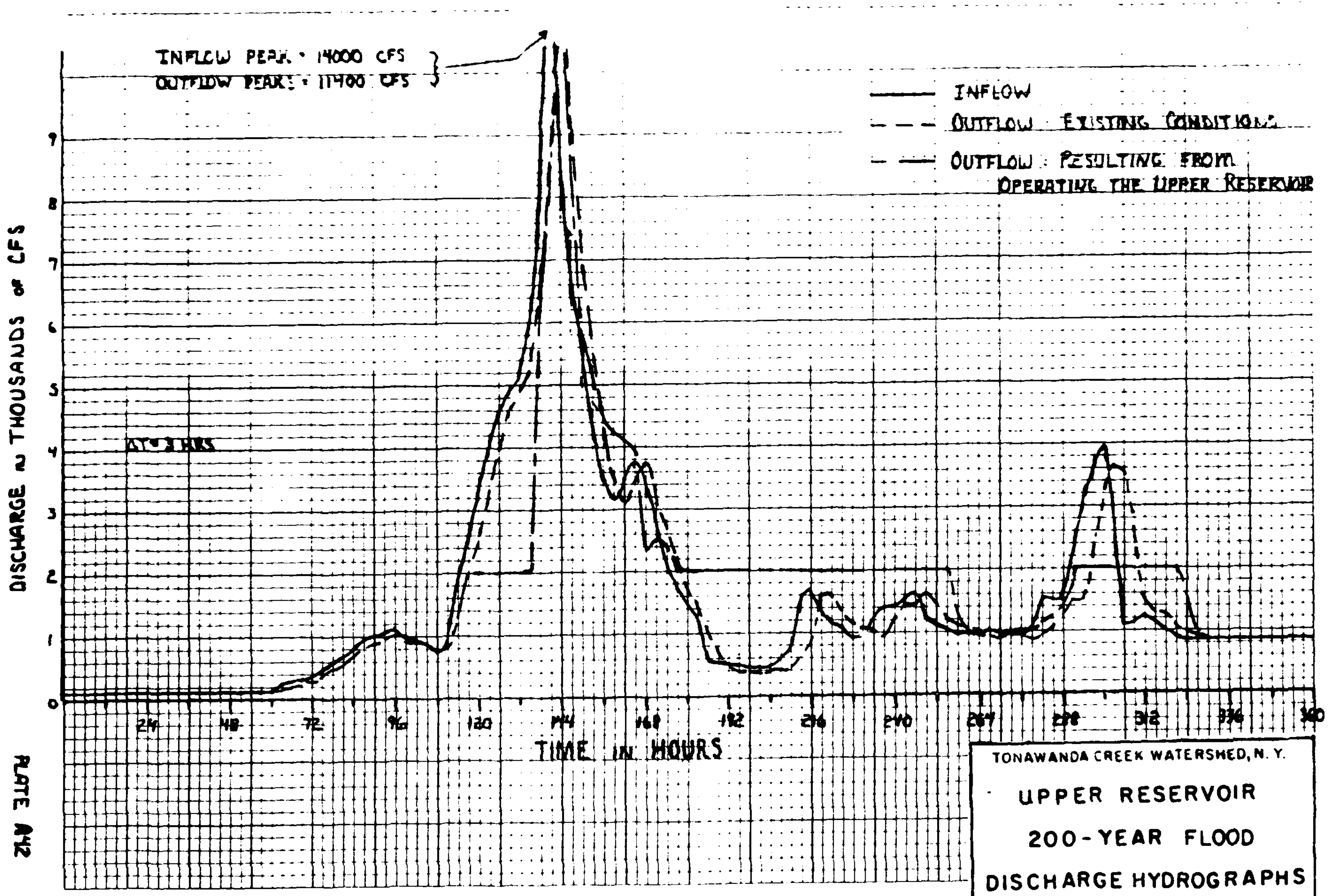
FOR TONAWANDA OVERFLOW

TO BLACK CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

K·E 46 1930



TONAWANDA CREEK WATERSHED, N. Y.

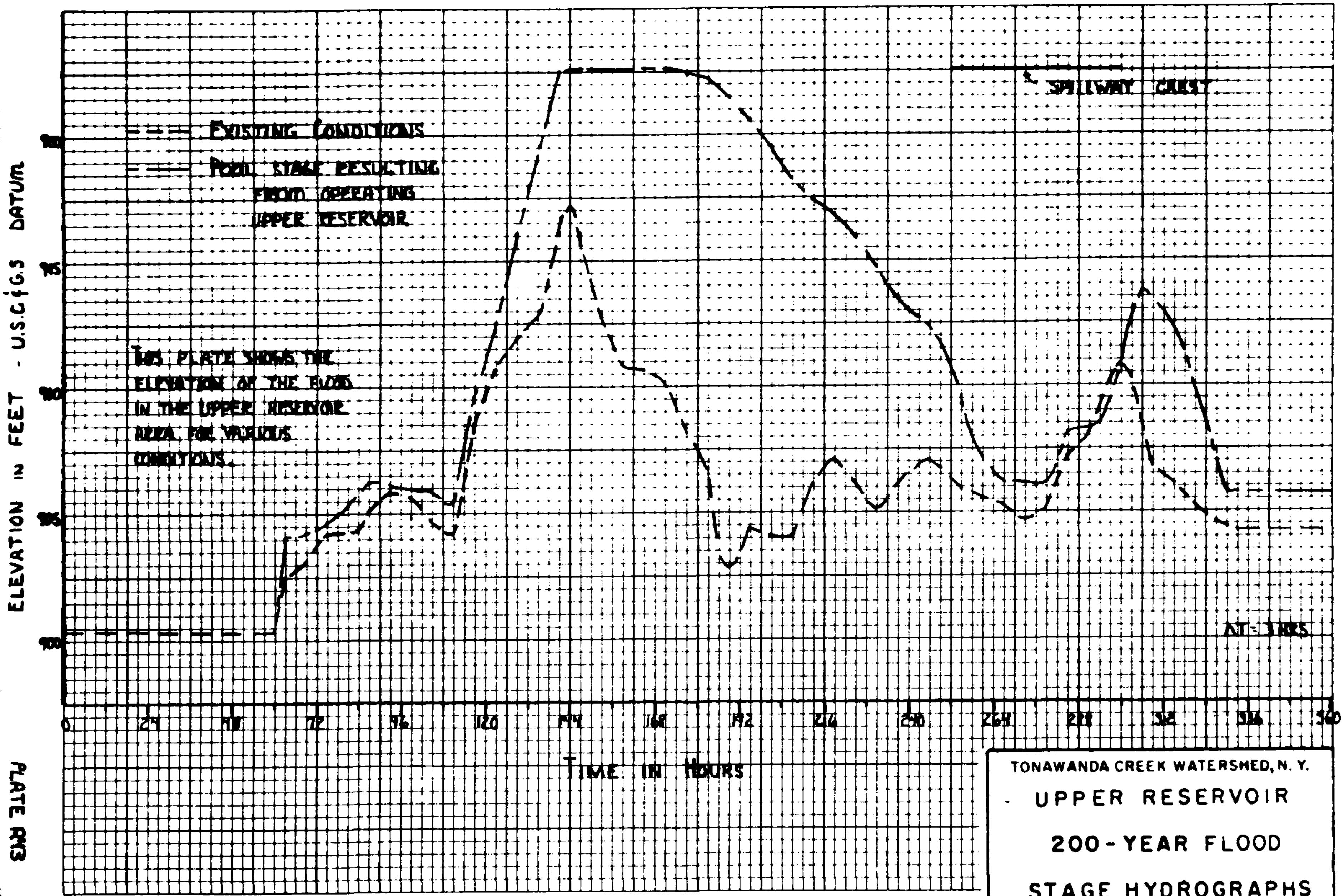
UPPER RESERVOIR

200-YEAR FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED 1979

PLATE A42



TONAWANDA CREEK WATERSHED, N. Y.

UPPER RESERVOIR

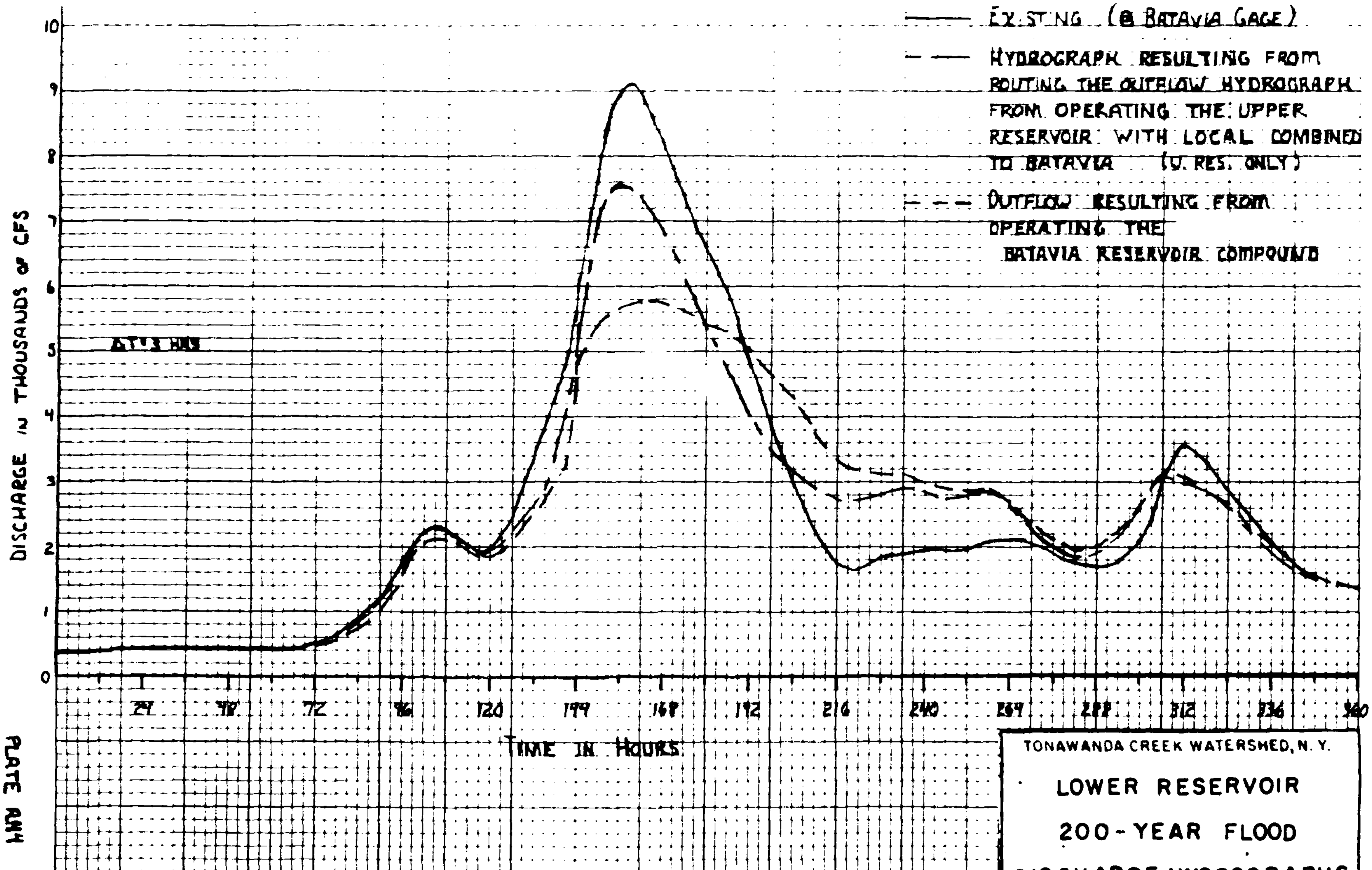
200-YEAR FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE RM3

K·E 46 1930



TONAWANDA CREEK WATERSHED, N. Y.

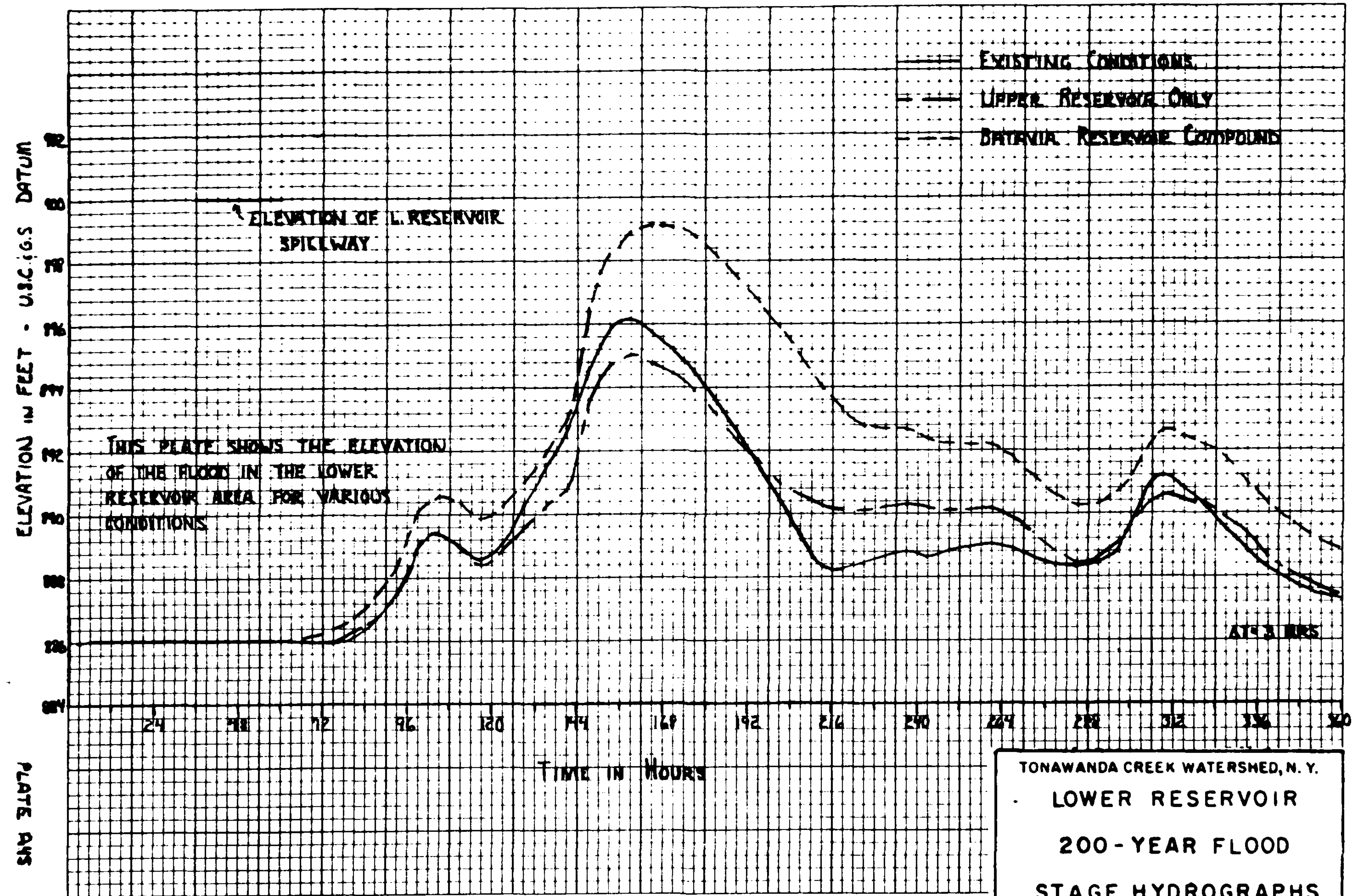
LOWER RESERVOIR

200-YEAR FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE AN4



TONAWANDA CREEK WATERSHED, N. Y.

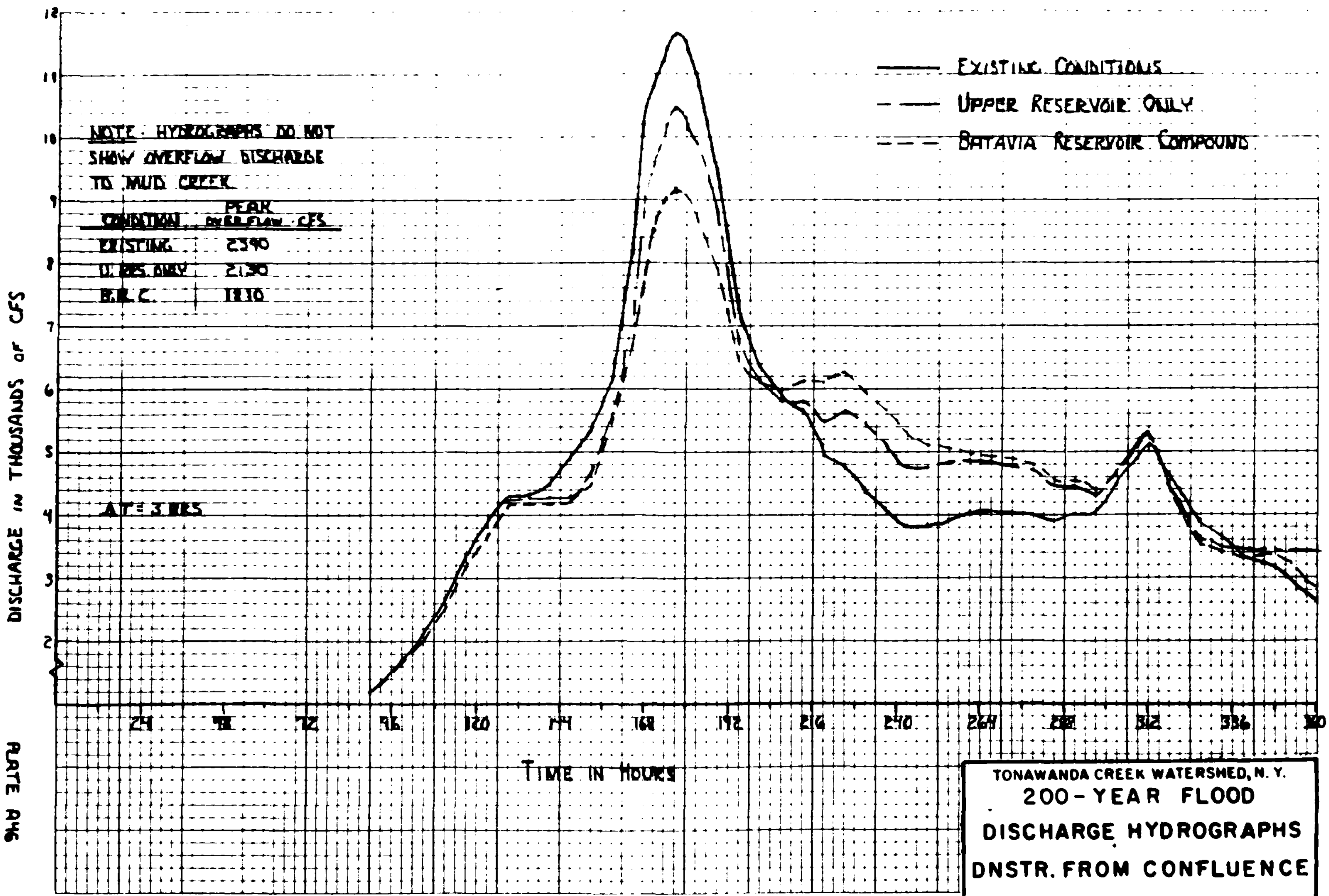
LOWER RESERVOIR

200-YEAR FLOOD

STAGE HYDROGRAPHS

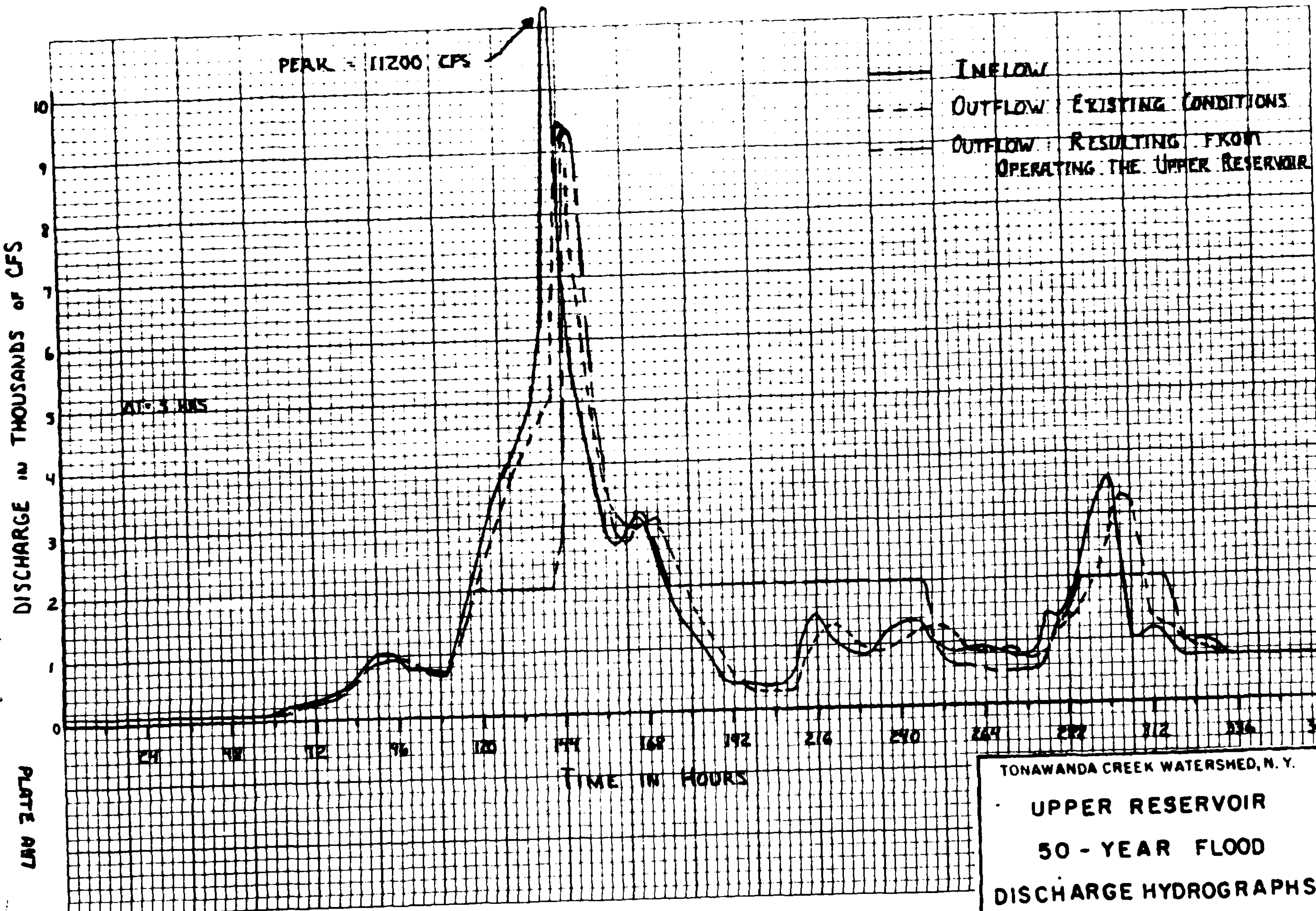
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A45



TONAWANDA CREEK WATERSHED, N. Y.
200-YEAR FLOOD
DISCHARGE HYDROGRAPHS
DNSTR. FROM CONFLUENCE
WITH LEDGE CREEK
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A46



TONAWANDA CREEK WATERSHED, N. Y.

UPPER RESERVOIR

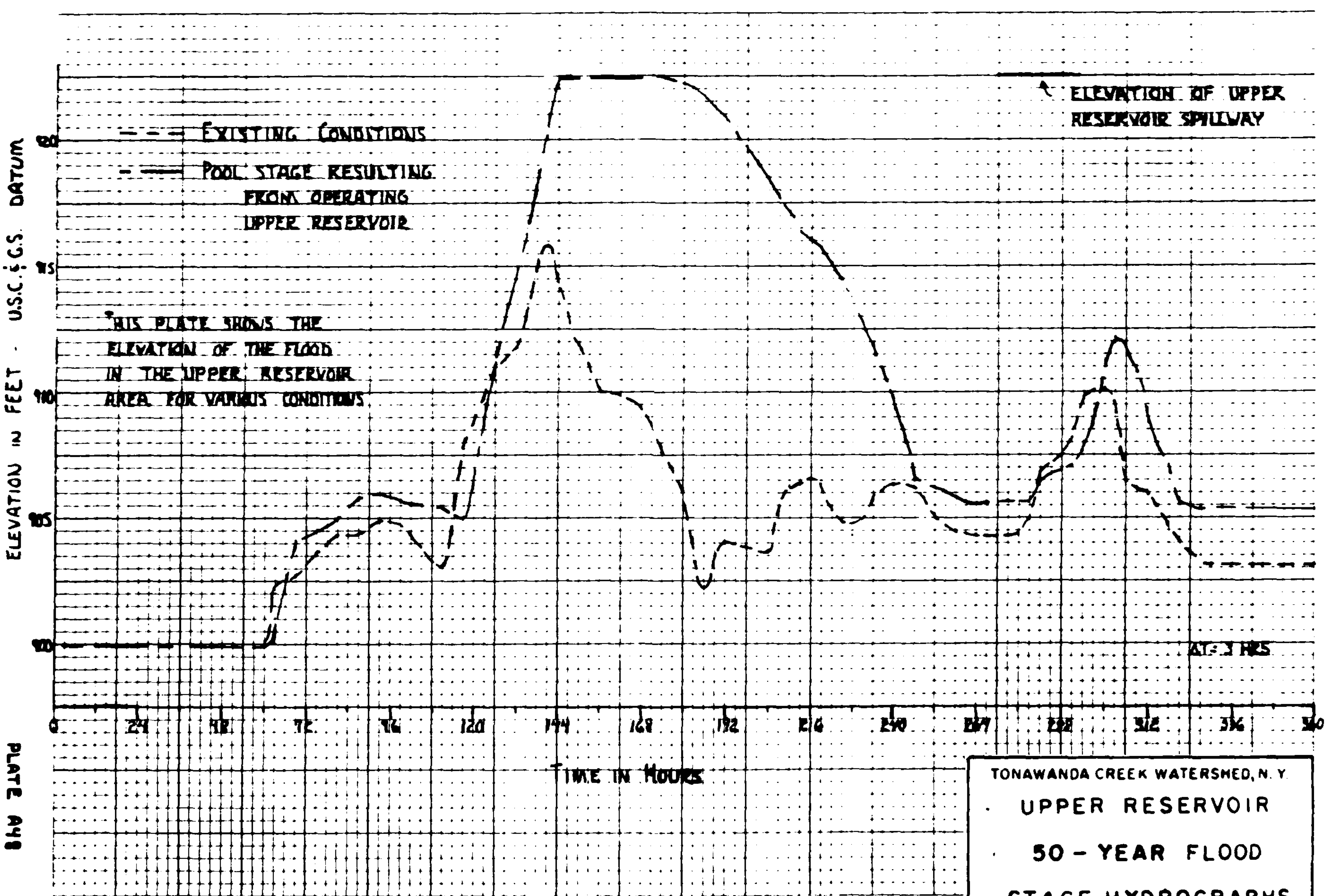
50 - YEAR FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A87

K+E 46 1930



TONAWANDA CREEK WATERSHED, N. Y.

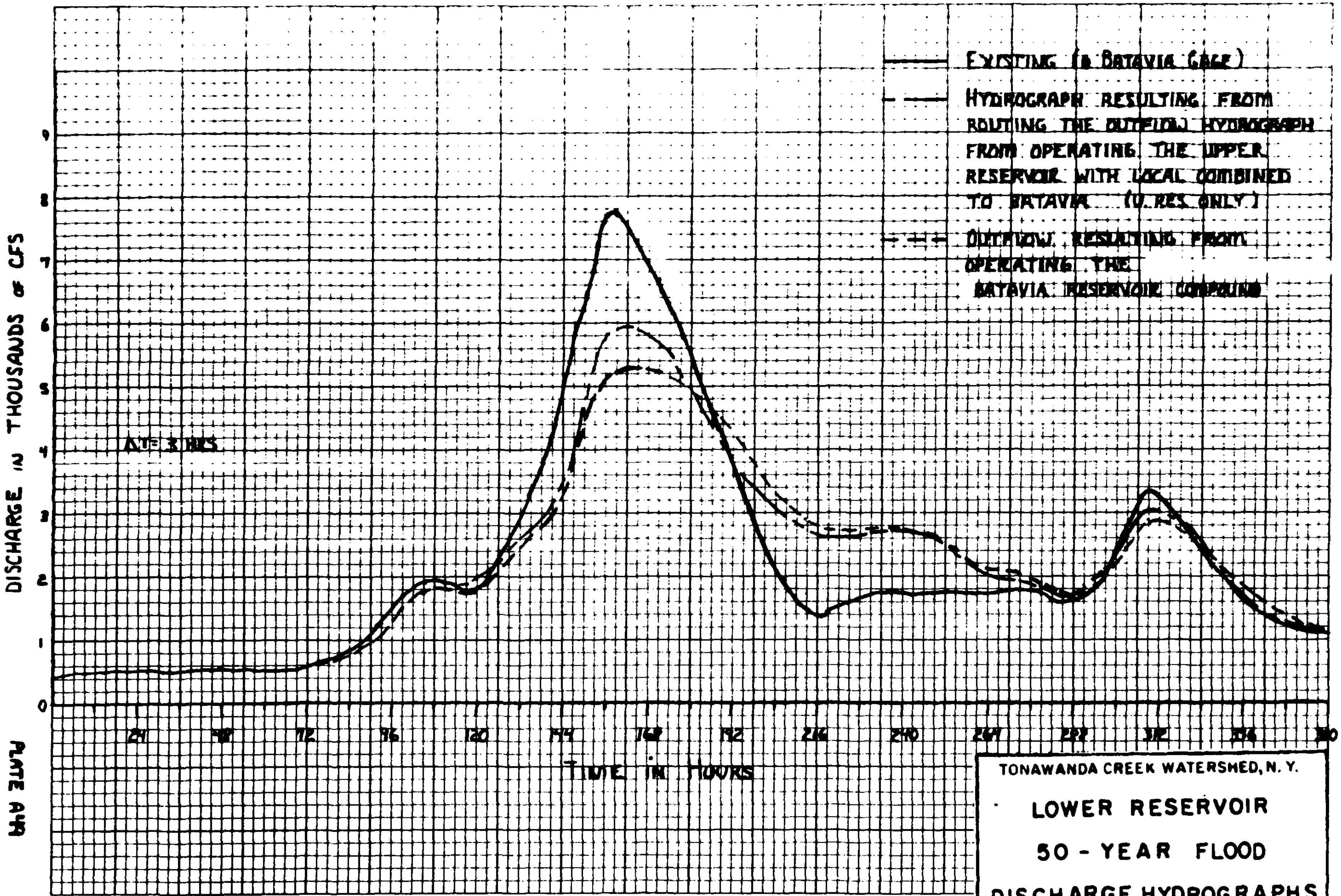
UPPER RESERVOIR

50 - YEAR FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A48



TONAWANDA CREEK WATERSHED, N. Y.

LOWER RESERVOIR

50 - YEAR FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

K•E

46 1930

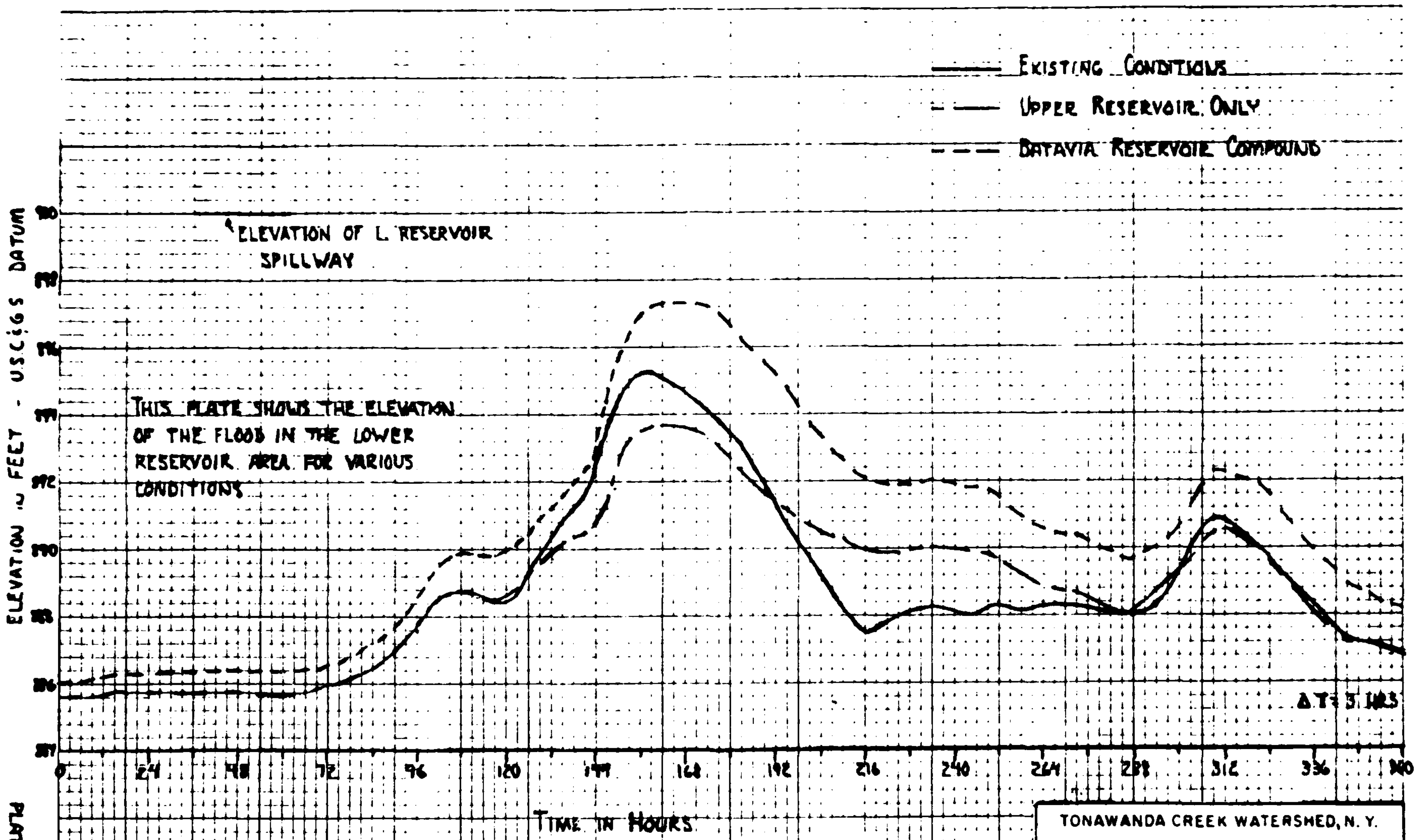


PLATE A50

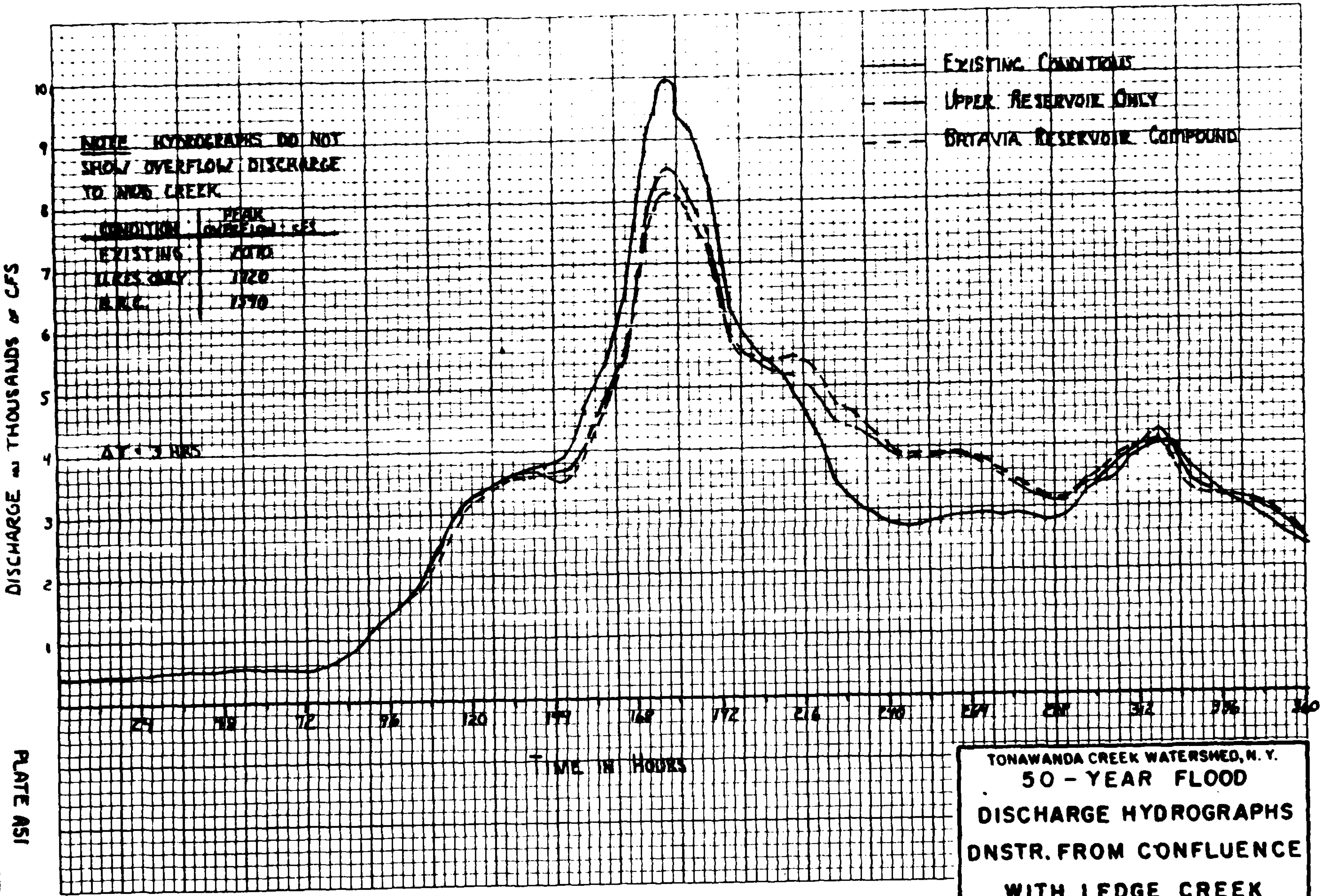
TONAWANDA CREEK WATERSHED, N. Y.

LOWER RESERVOIR

50 - YEAR FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, N. Y.

50 - YEAR FLOOD

DISCHARGE HYDROGRAPHS

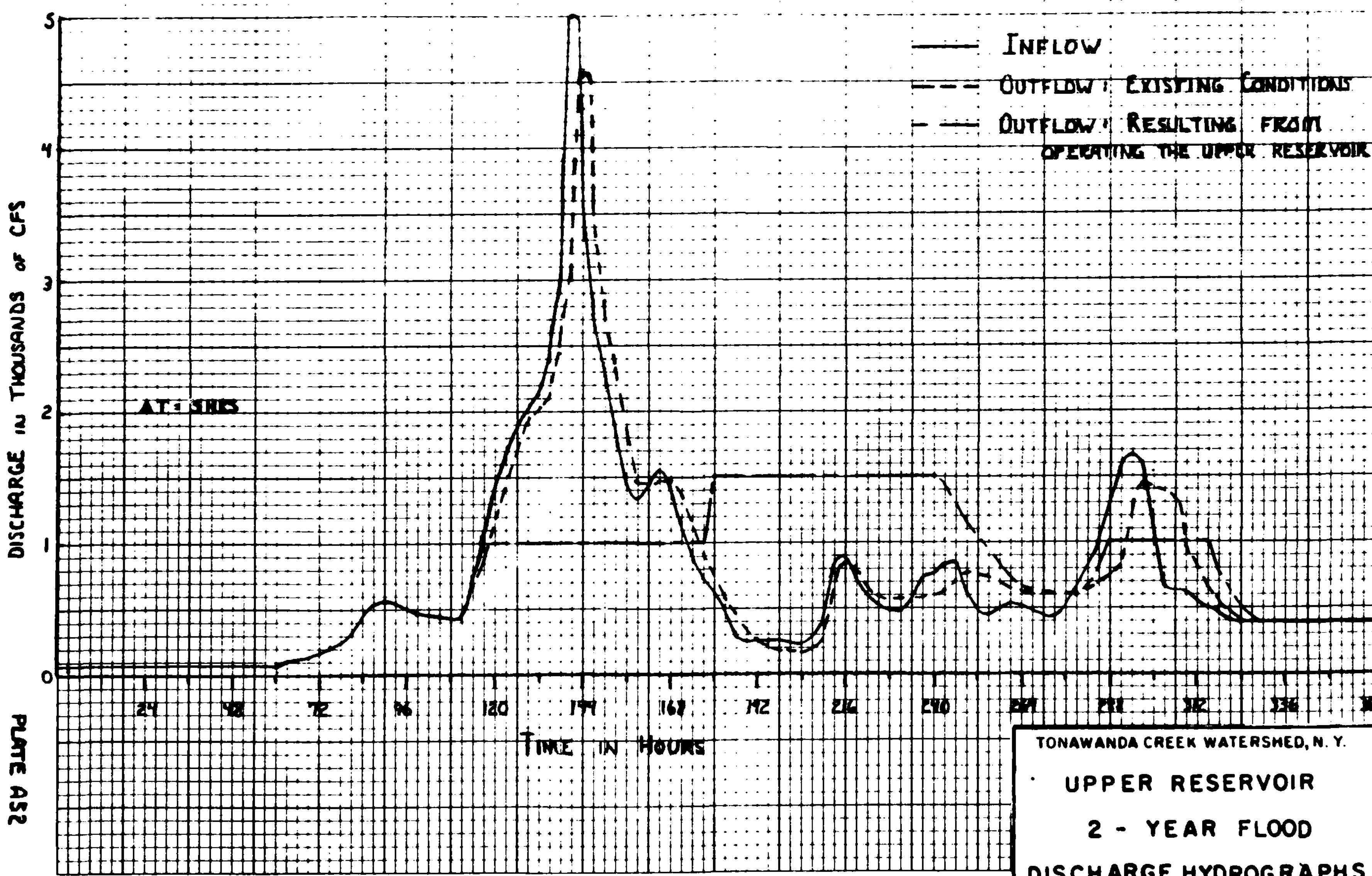
DNSTR. FROM CONFLUENCE

WITH LEDGE CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A51



TONAWANDA CREEK WATERSHED, N. Y.

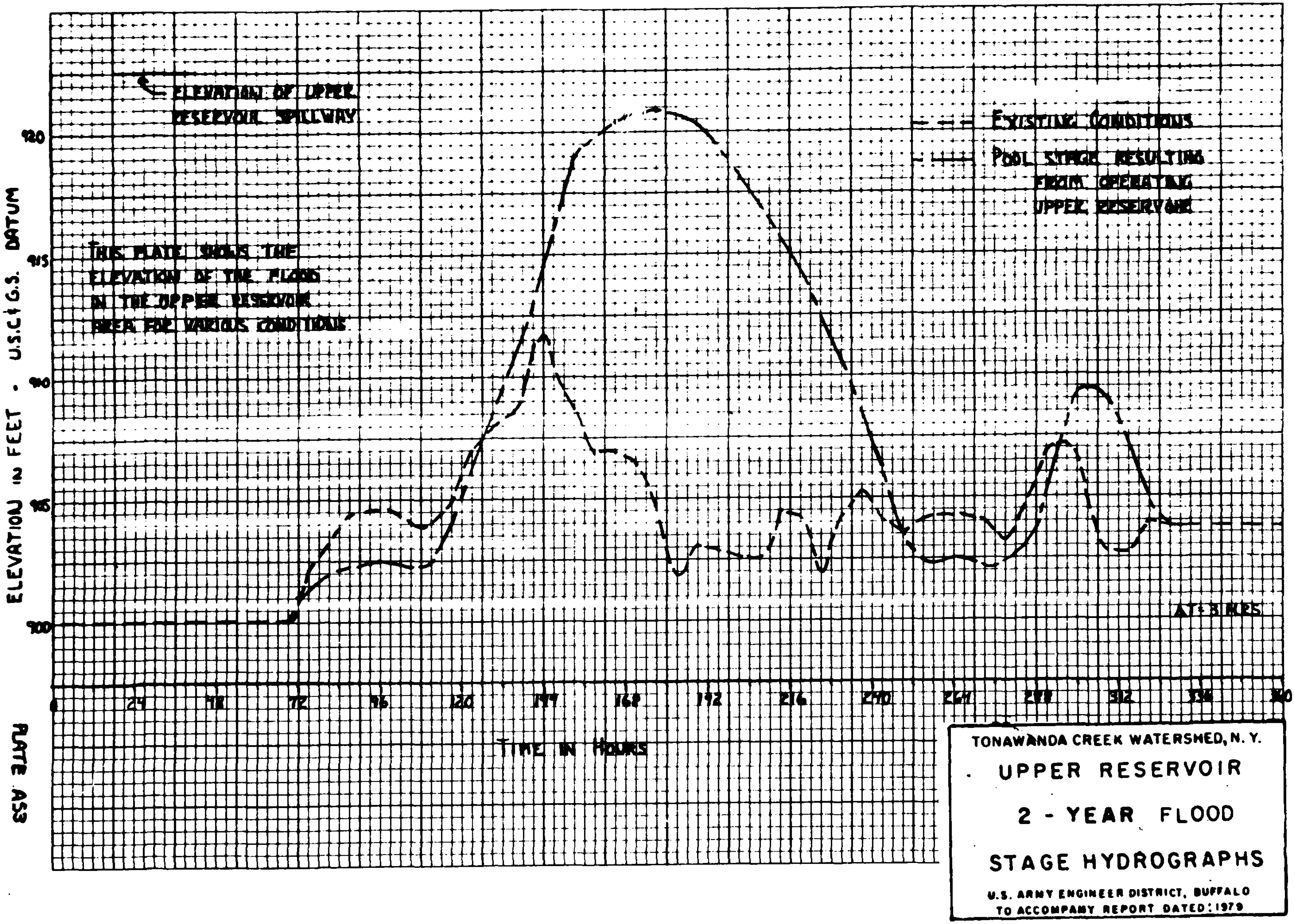
UPPER RESERVOIR

2 - YEAR FLOOD

DISCHARGE HYDROGRAPHS

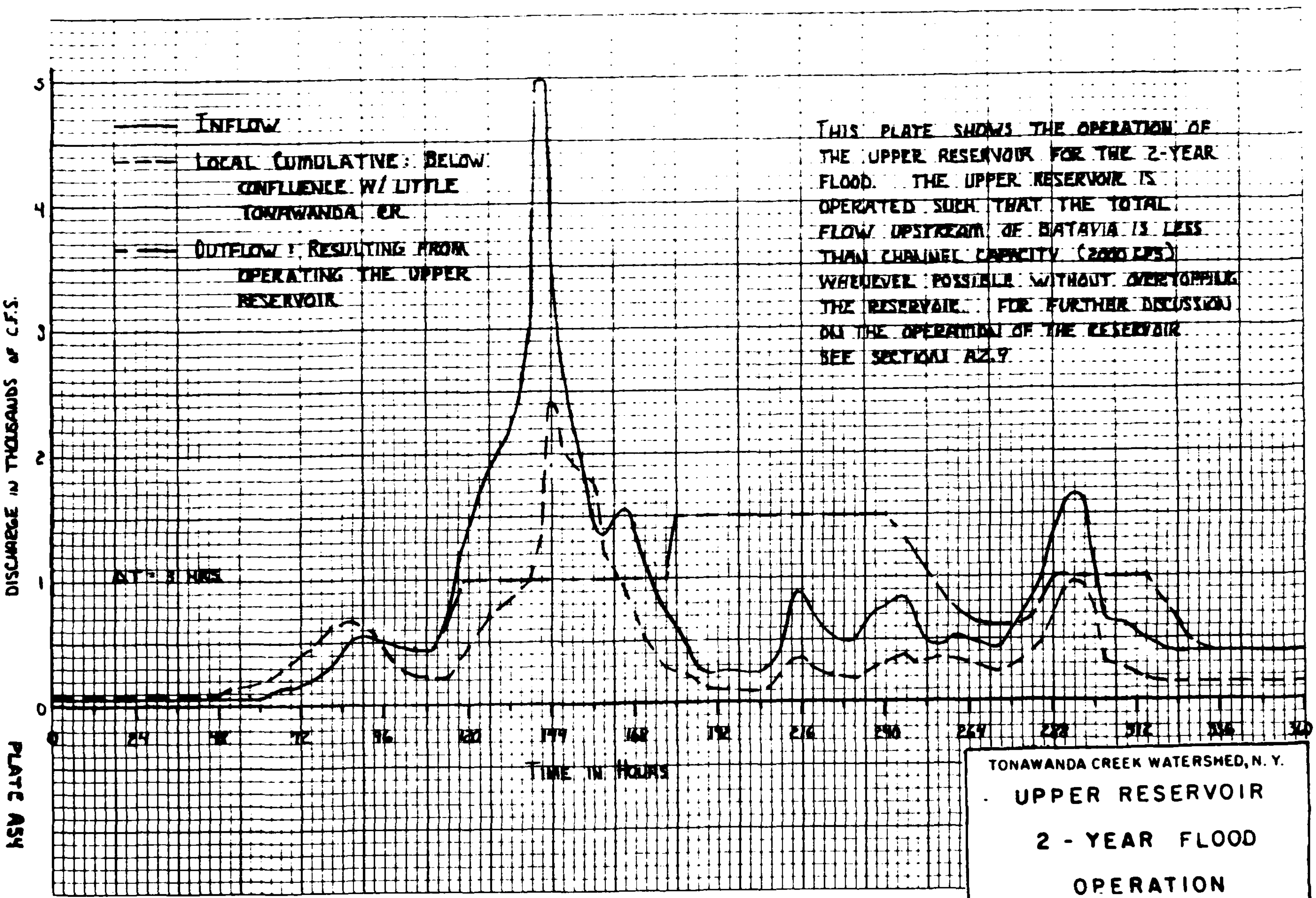
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A52



ELEVATION OF UPPER RESERVOIR SPILLWAY
EXISTING CONDITIONS
POOL STAGE RESULTING FROM OPERATING UPPER RESERVOIR
THIS PLATE SHOWS THE ELEVATION OF THE FLOOD IN THE UPPER RESERVOIR AREA FOR VARIOUS CONDITIONS
ELEVATION IN FEET - U.S.C.& G.S. DATUM
920
915
910
905
900
AT=3 HRS
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
360
TIME IN HOURS
TONAWANDA CREEK WATERSHED, N.Y.
UPPER RESERVOIR
2 - YEAR FLOOD
STAGE HYDROGRAPHS
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A53



TONAWANDA CREEK WATERSHED, N. Y.

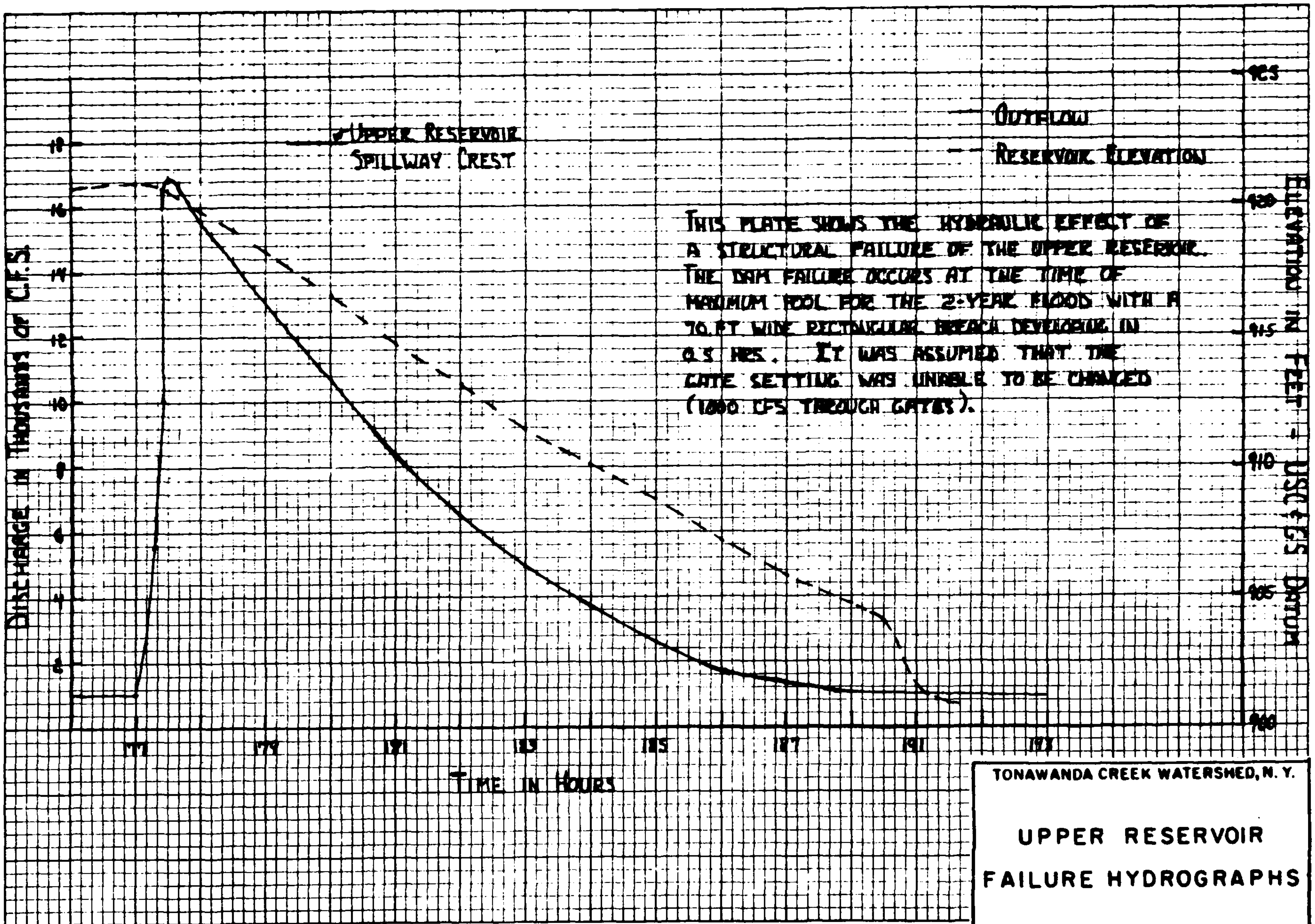
UPPER RESERVOIR

2 - YEAR FLOOD

OPERATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A54



TONAWANDA CREEK WATERSHED, N. Y.

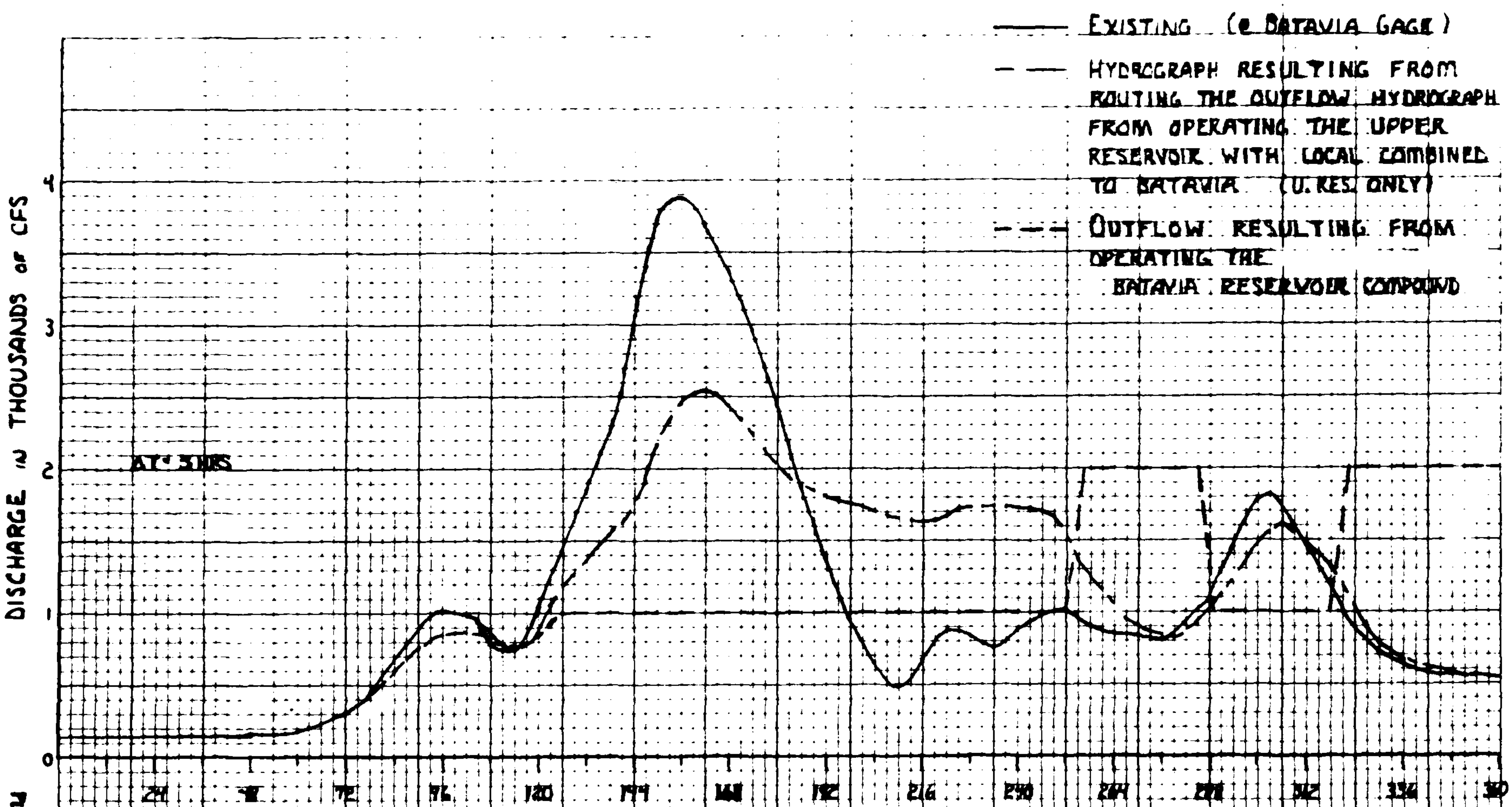
UPPER RESERVOIR

FAILURE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A54a

K•E 46 1930



TONAWANDA CREEK WATERSHED, N. Y.

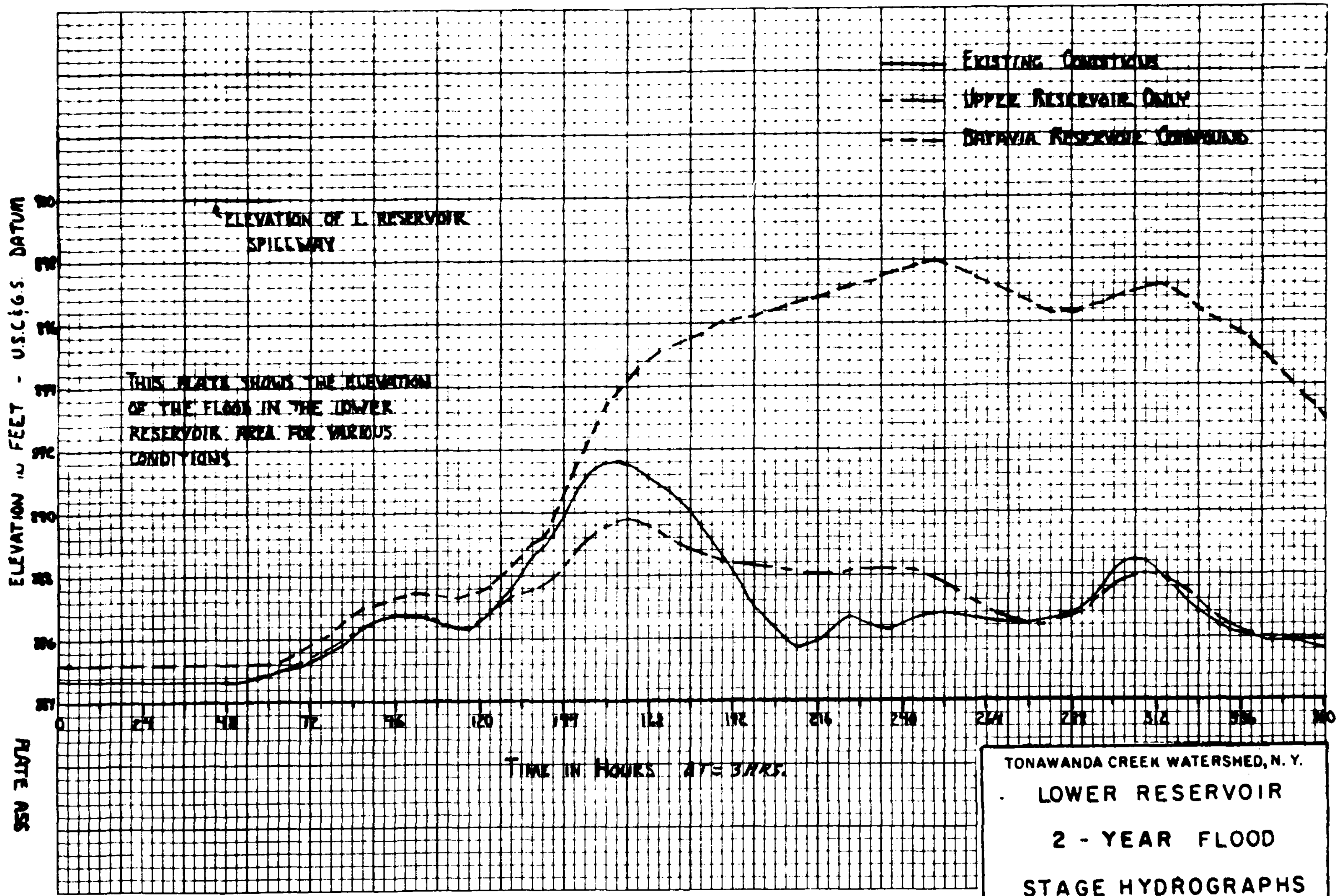
LOWER RESERVOIR

2 - YEAR FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A55



TONAWANDA CREEK WATERSHED, N. Y.

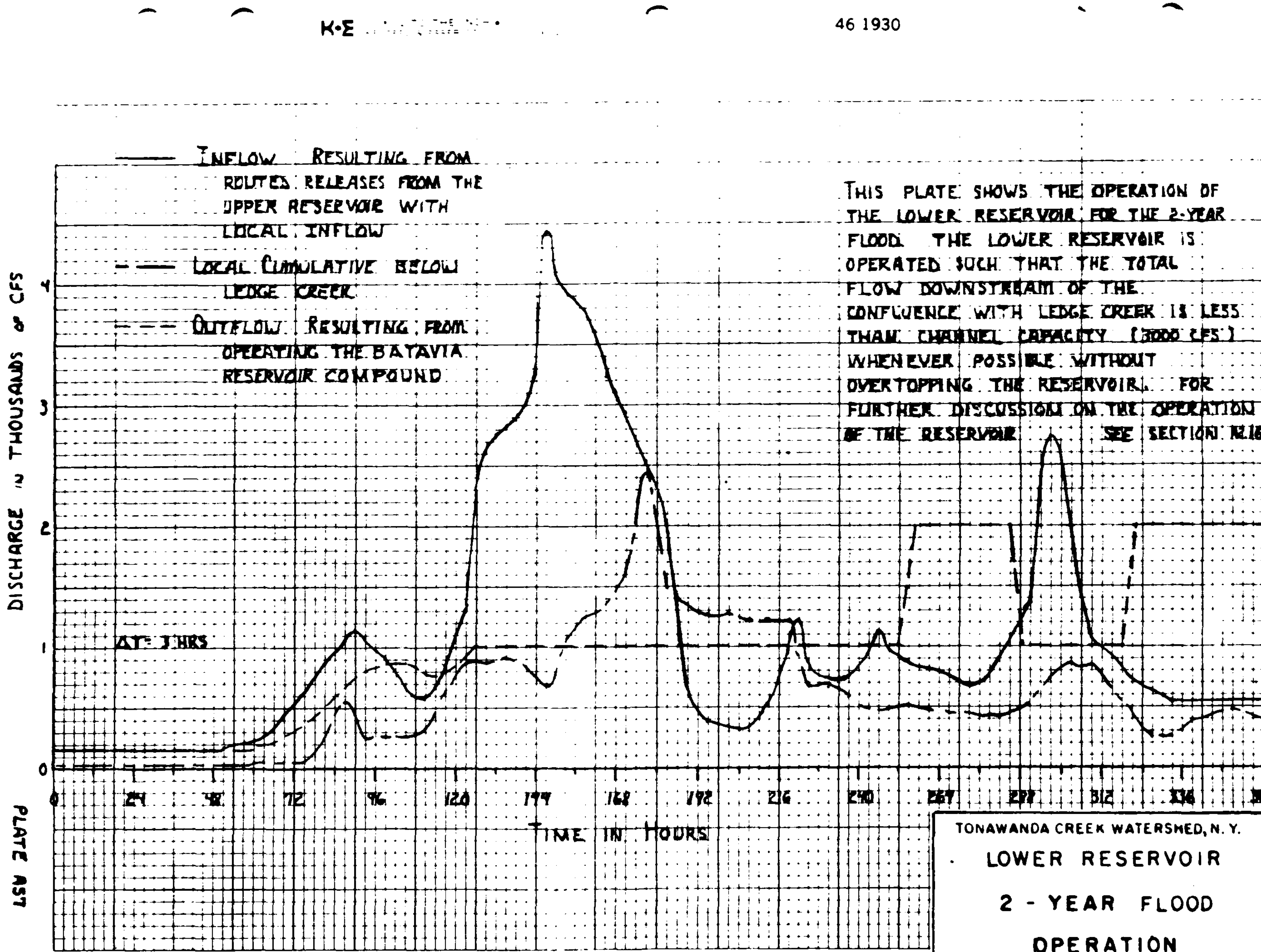
LOWER RESERVOIR

2 - YEAR FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A56



TONAWANDA CREEK WATERSHED, N. Y.

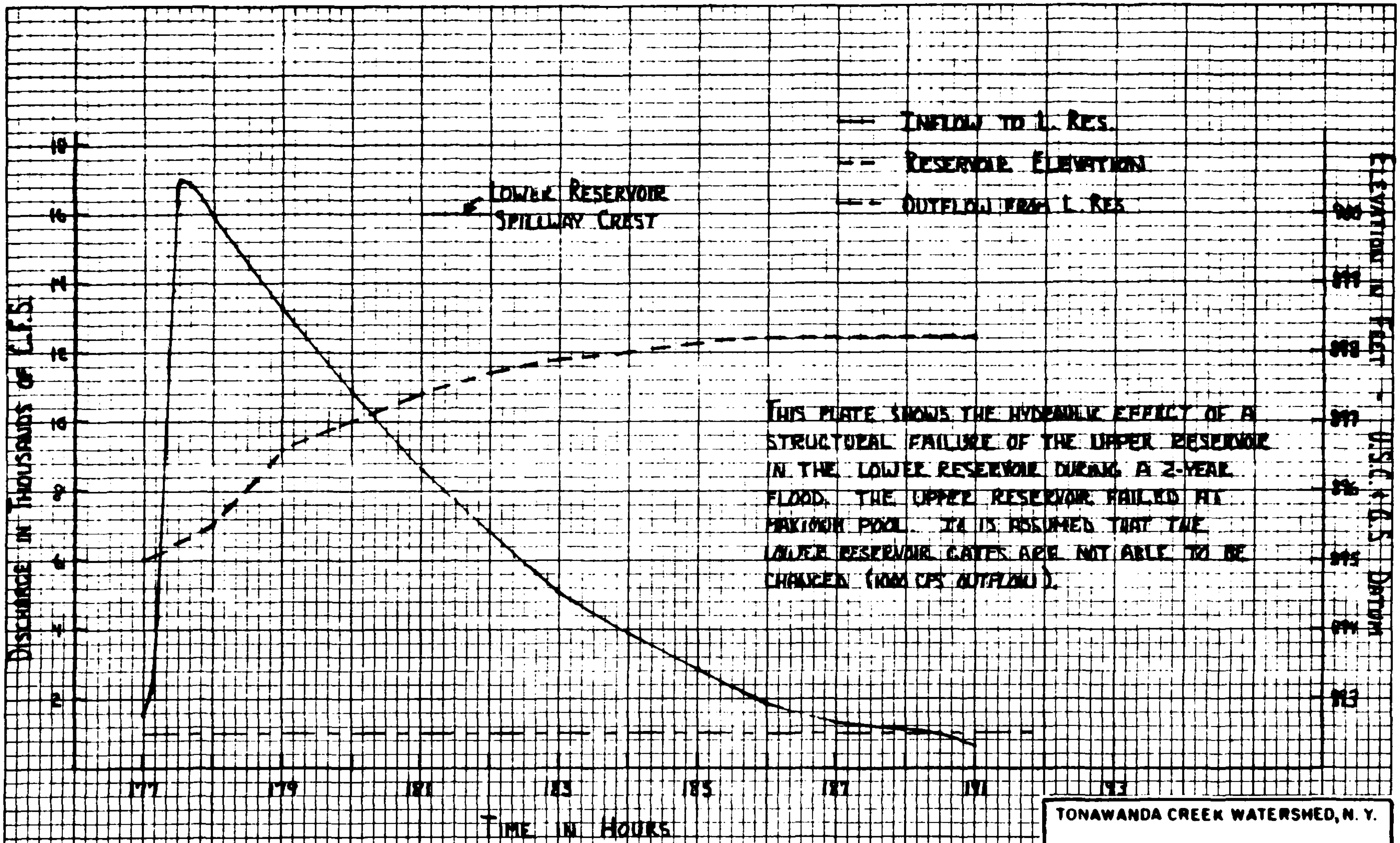
LOWER RESERVOIR

2 - YEAR FLOOD

OPERATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A57

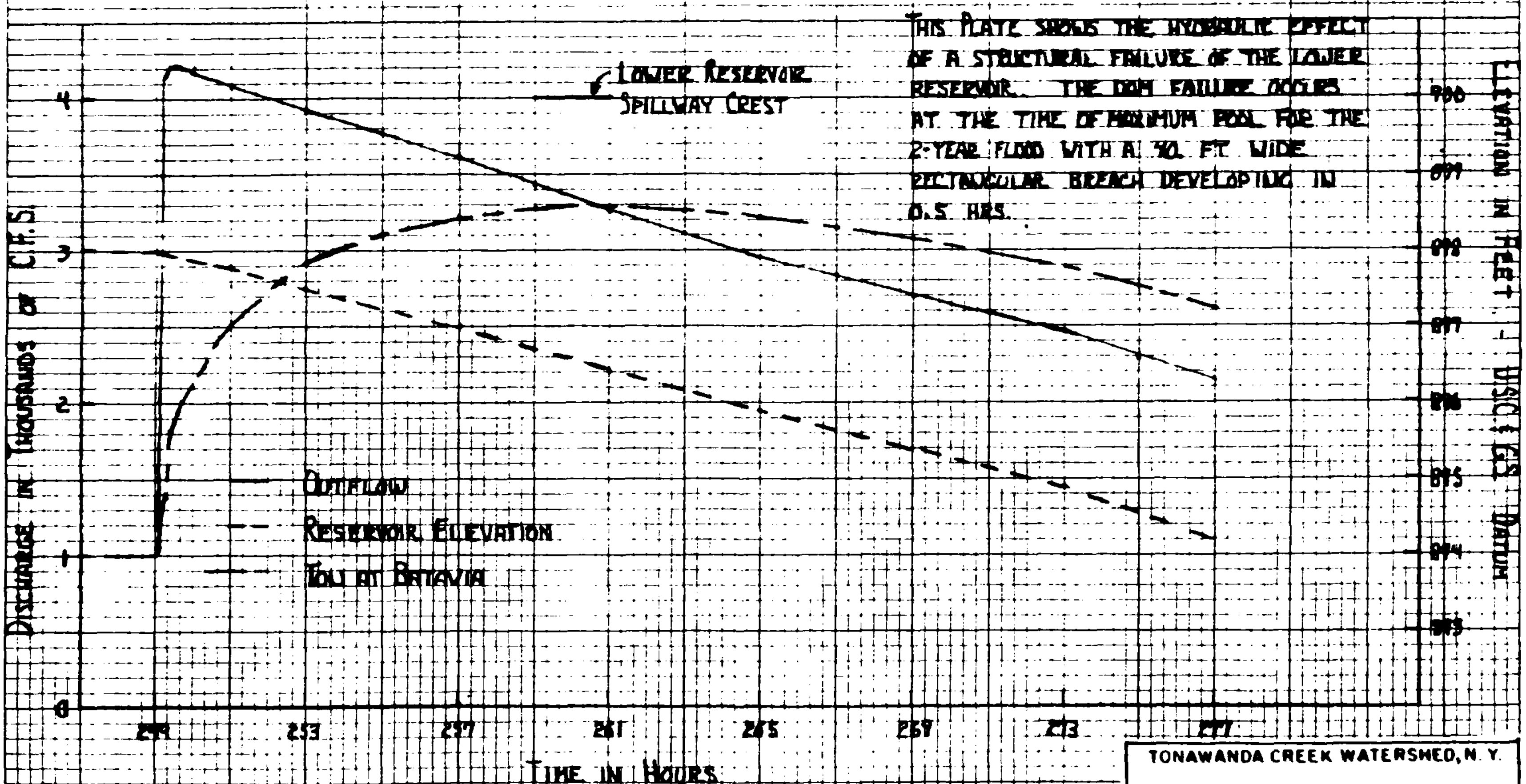


TONAWANDA CREEK WATERSHED, N. Y.

LOWER RESERVOIR RESPONSE TO UPPER RESERVOIR FAILURE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A57a

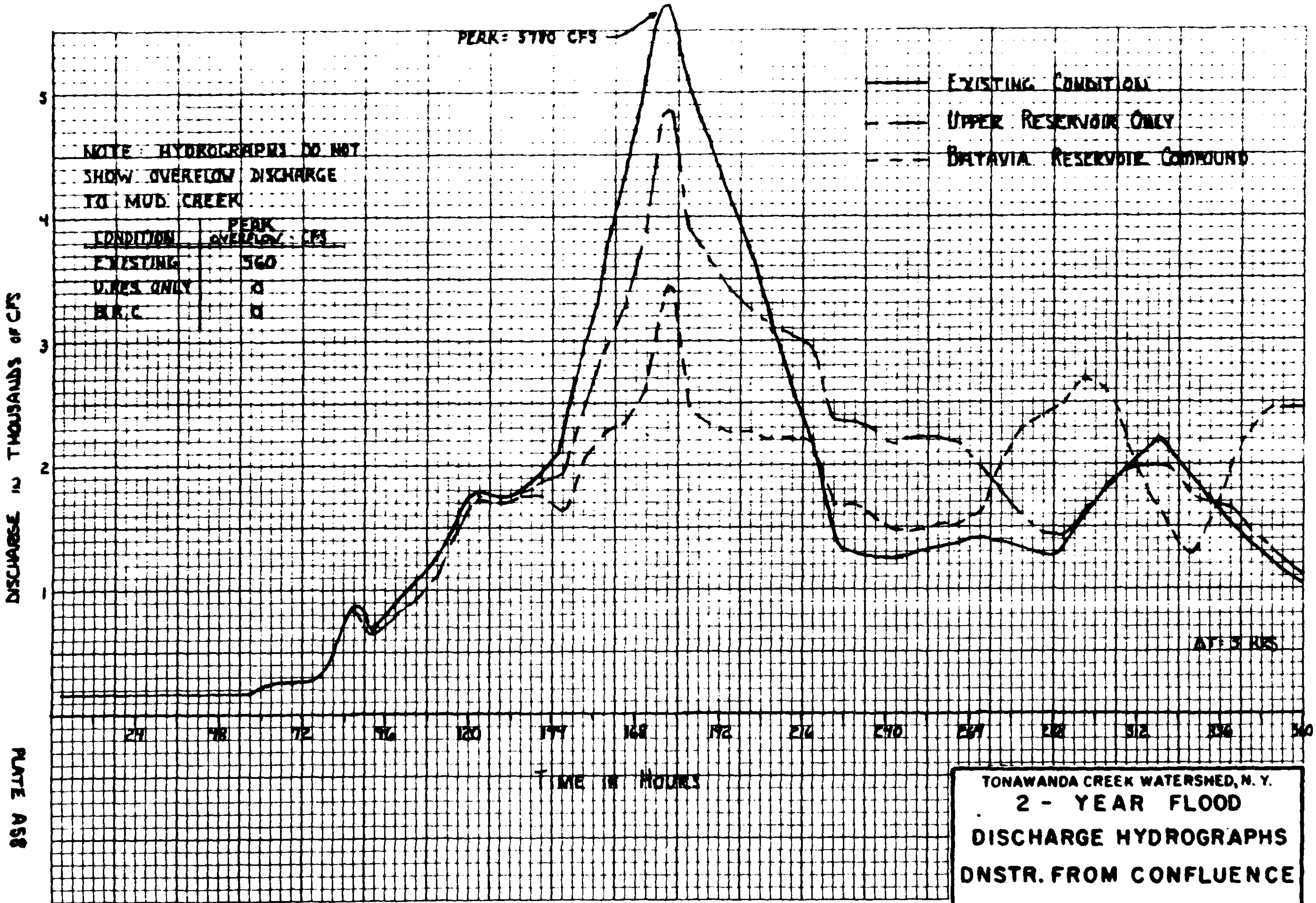


TONAWANDA CREEK WATERSHED, N. Y.

LOWER RESERVOIR FAILURE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A57b



TONAWANDA CREEK WATERSHED, N. Y.

2 - YEAR FLOOD

DISCHARGE HYDROGRAPHS

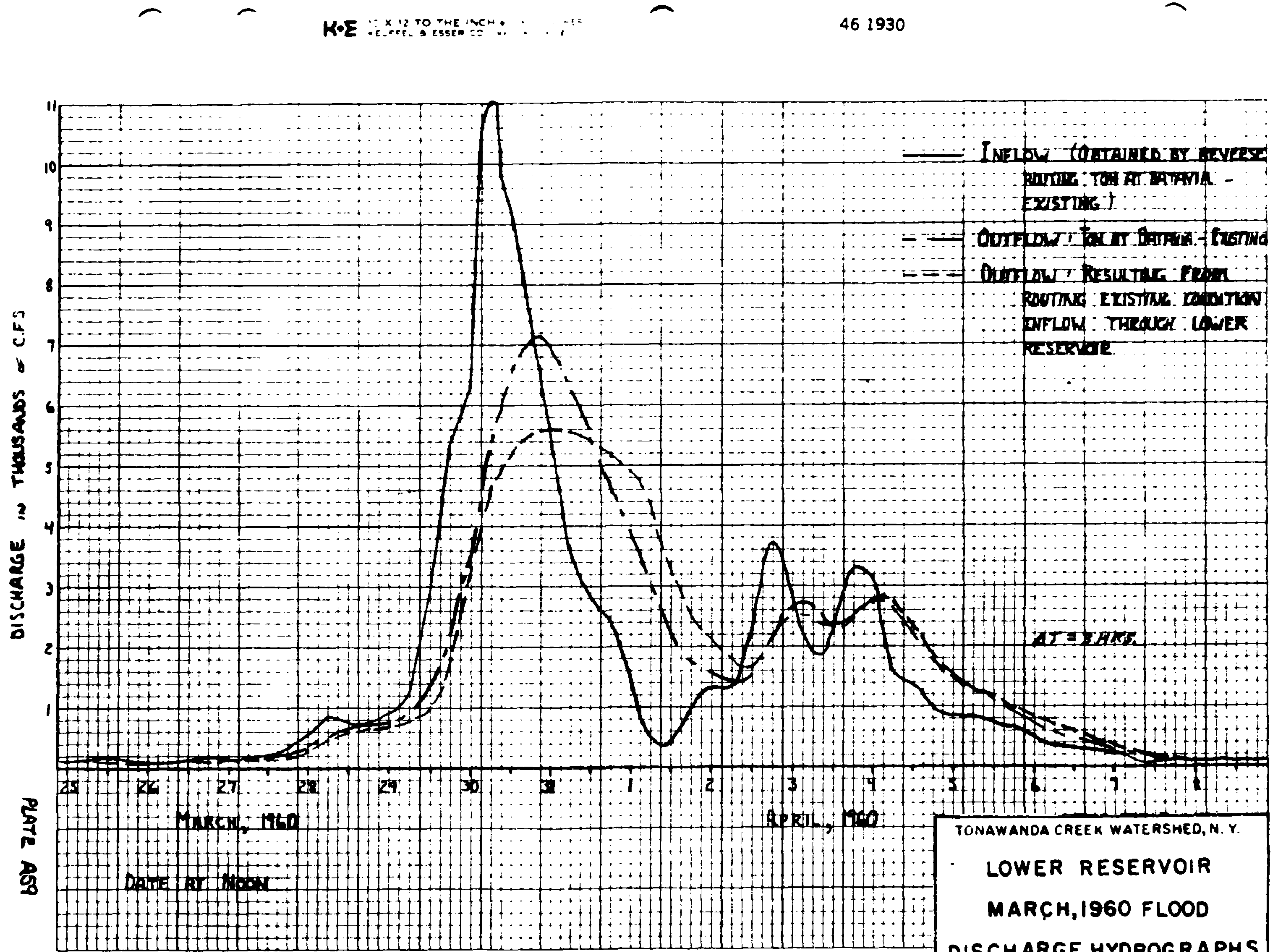
DNSTR. FROM CONFLUENCE

WITH LEDGE CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A58



TONAWANDA CREEK WATERSHED, N. Y.

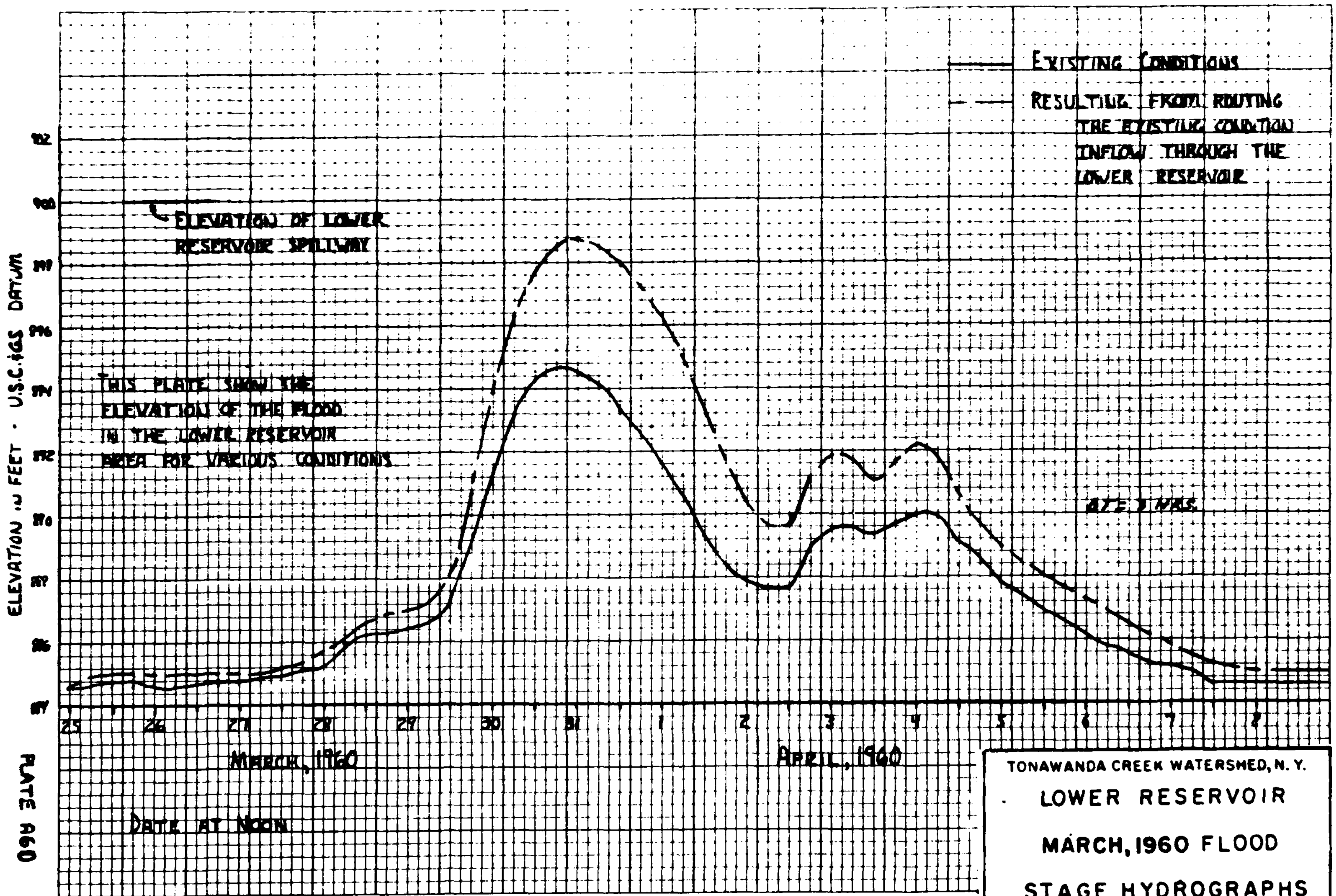
LOWER RESERVOIR

MARÇH, 1960 FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A59



TONAWANDA CREEK WATERSHED, N. Y.

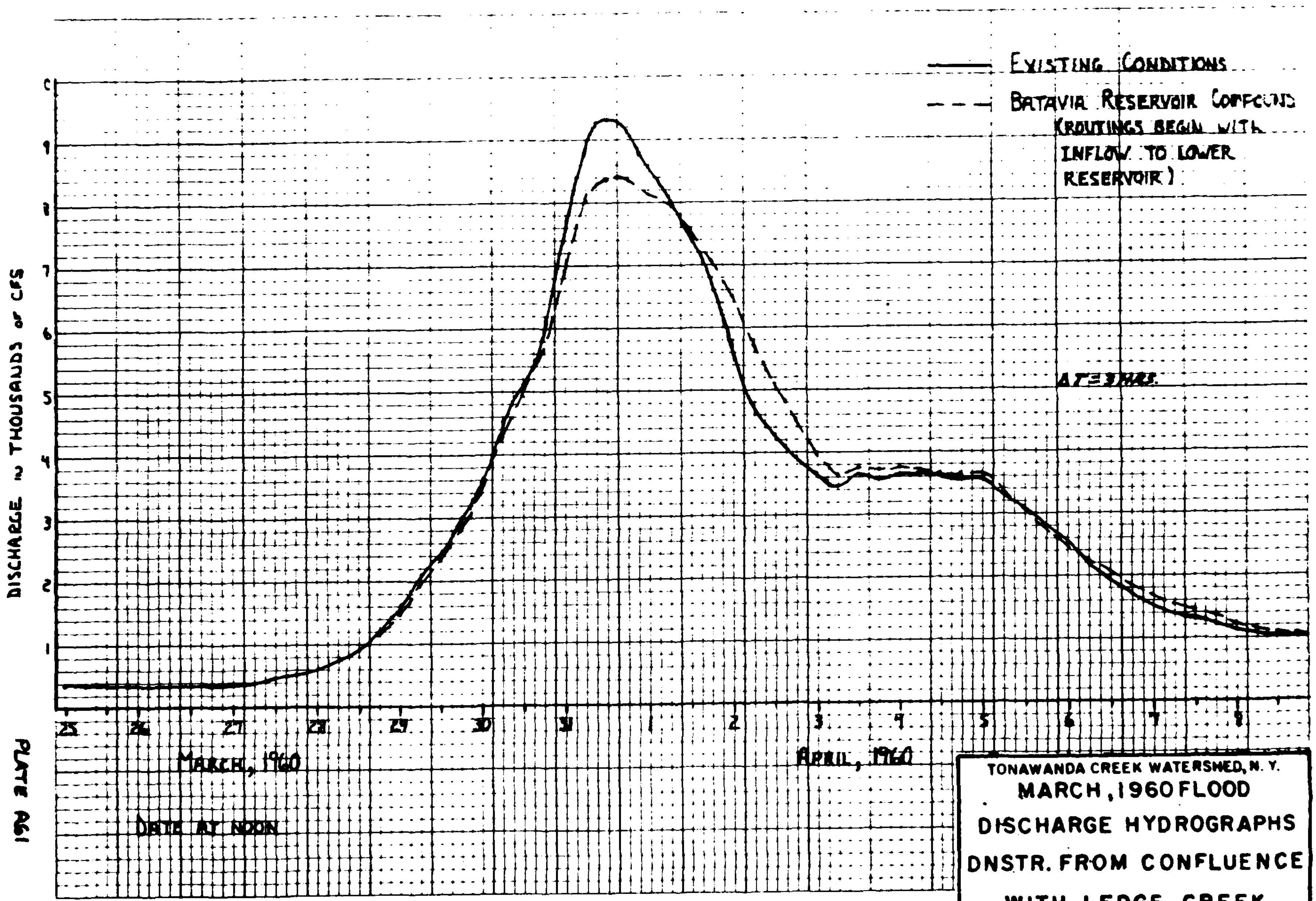
LOWER RESERVOIR

MARCH, 1960 FLOOD

STAGE HYDROGRAPHS

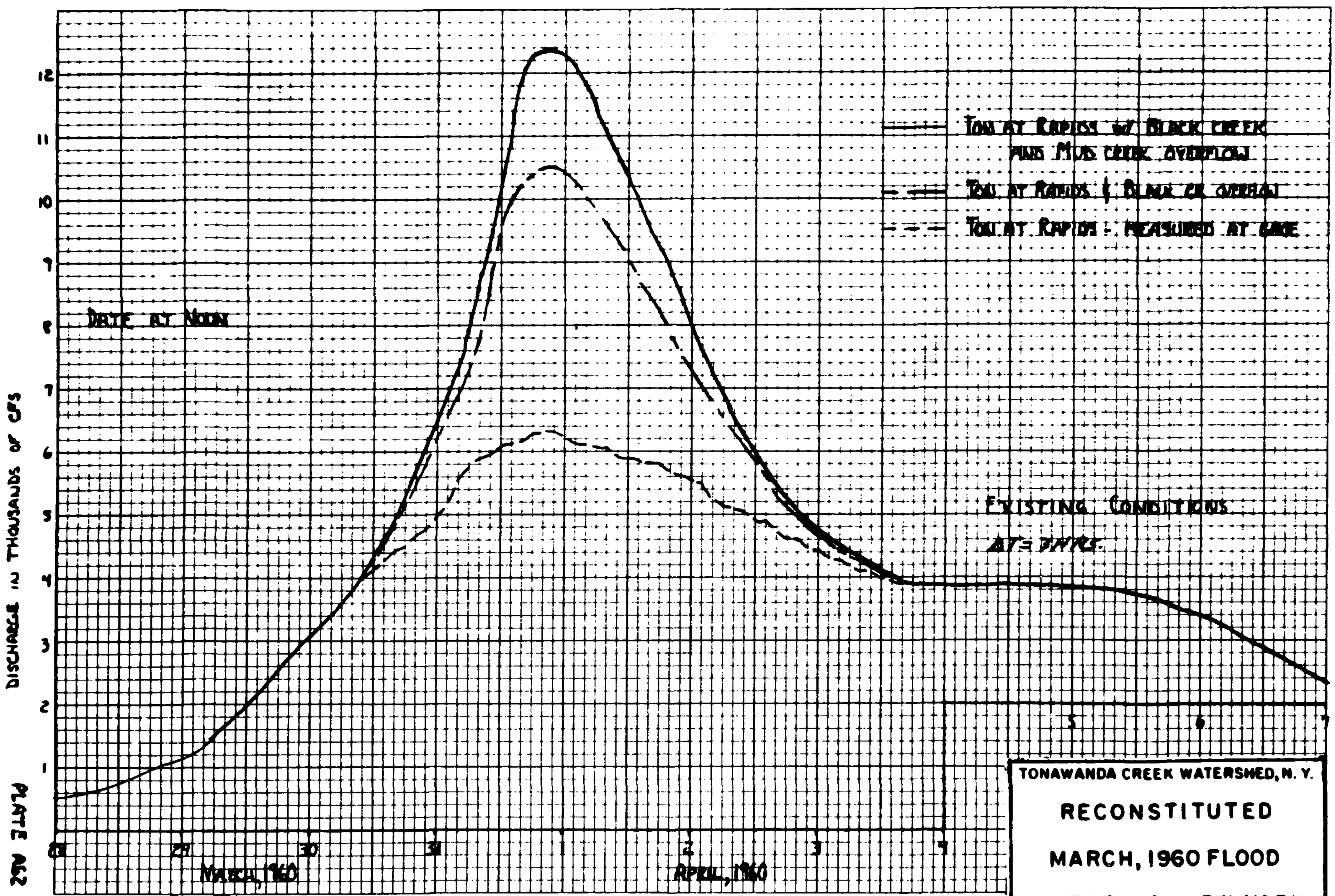
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A60



TONAWANDA CREEK WATERSHED, N. Y.
MARCH, 1960 FLOOD
DISCHARGE HYDROGRAPHS
DNSTR. FROM CONFLUENCE
WITH LEDGE CREEK
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A61



TONAWANDA CREEK WATERSHED, N. Y.

RECONSTITUTED

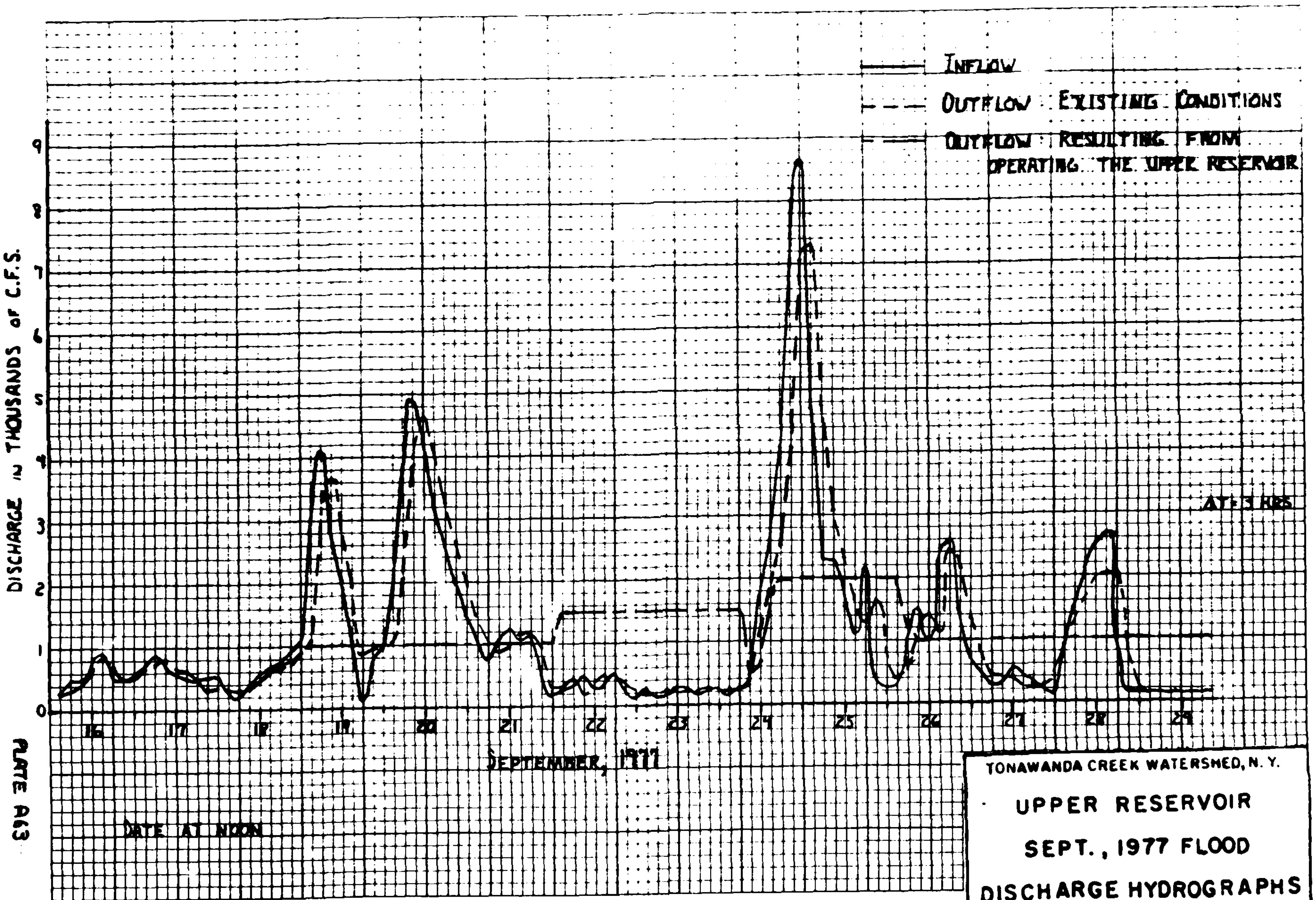
MARCH, 1960 FLOOD

AT RAPIDS, NEW YORK

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A62

K•E 46 1930



TONAWANDA CREEK WATERSHED, N. Y.

UPPER RESERVOIR

SEPT., 1977 FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A63

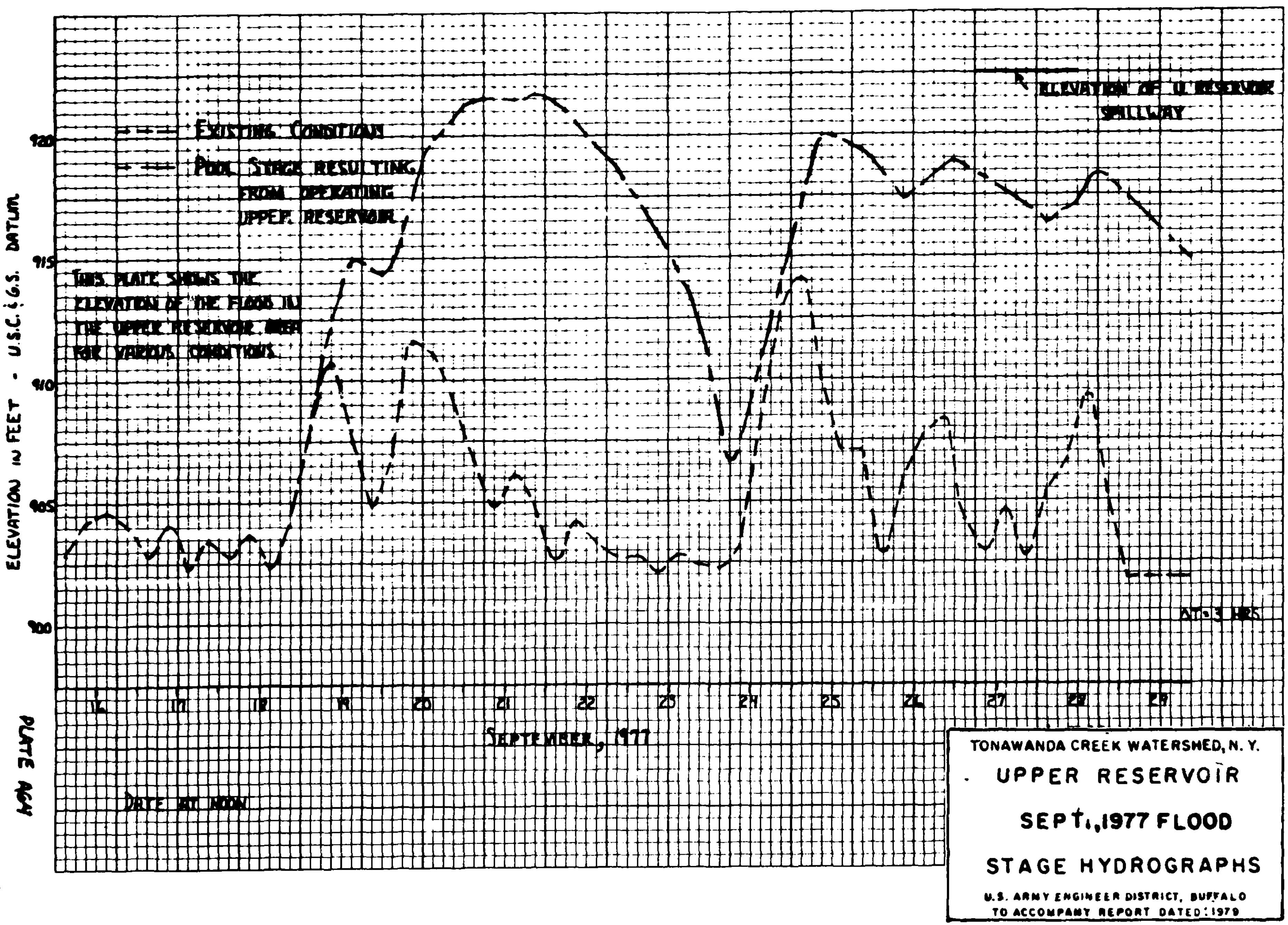
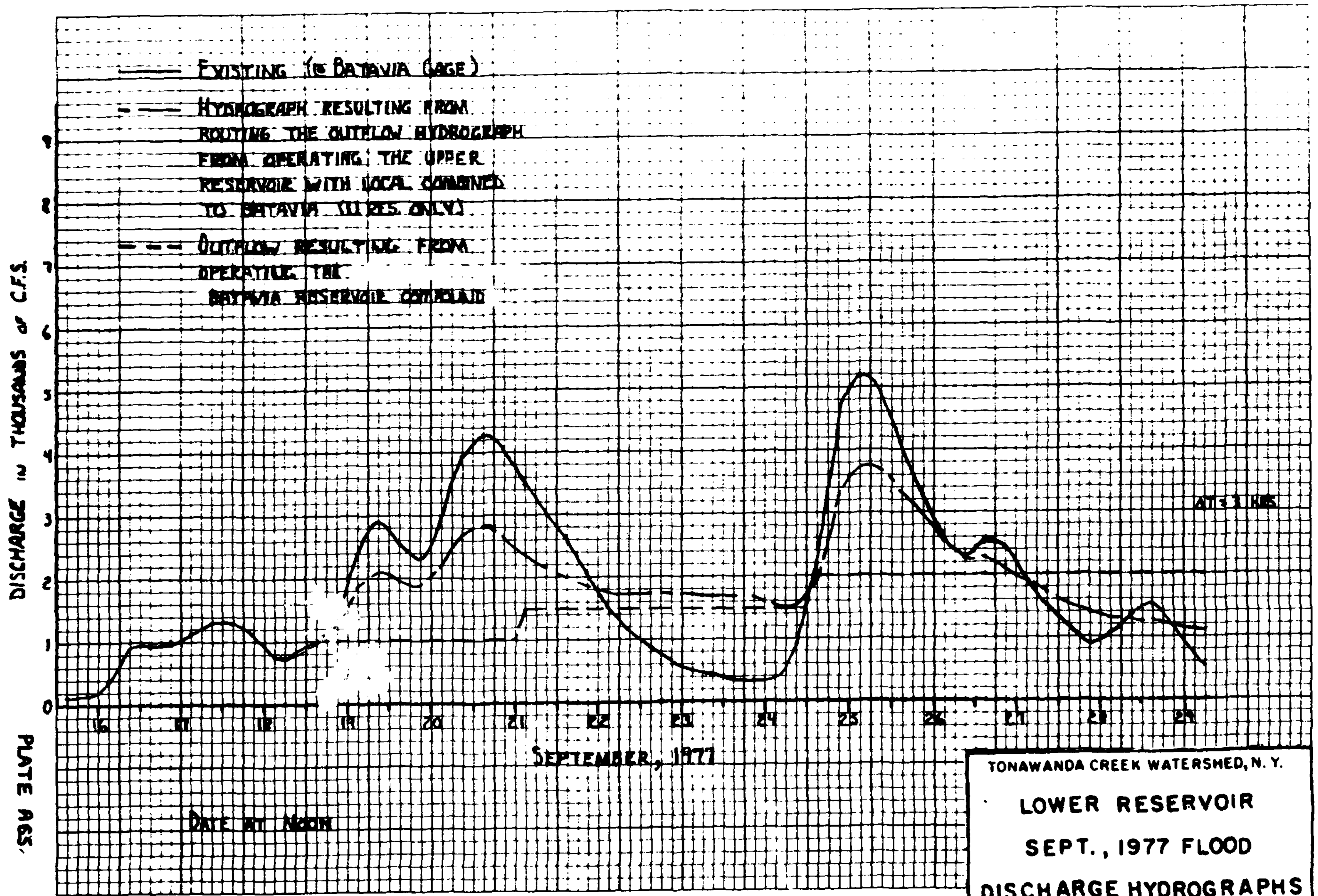

ELEVATION OF U. RESERVOIR SPILLWAY
EXISTING CONDITION
POOL STAGE RESULTING FROM OPERATING UPPER RESERVOIR
THIS PLATE SHOWS THE ELEVATION OF THE FLOOD IN THE UPPER RESERVOIR AREA FOR VARIOUS CONDITIONS.
920
915
910
905
900
ELEVATION IN FEET - U.S.C.&G.S. DATUM
ΔT=3 HRS
16
17
18
19
20
21
22
23
24
25
26
27
28
29
SEPTEMBER, 1977
DATE AT NOON
TONAWANDA CREEK WATERSHED, N. Y.
UPPER RESERVOIR
SEPT. 1977 FLOOD
STAGE HYDROGRAPHS
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE AG4



TONAWANDA CREEK WATERSHED, N. Y.

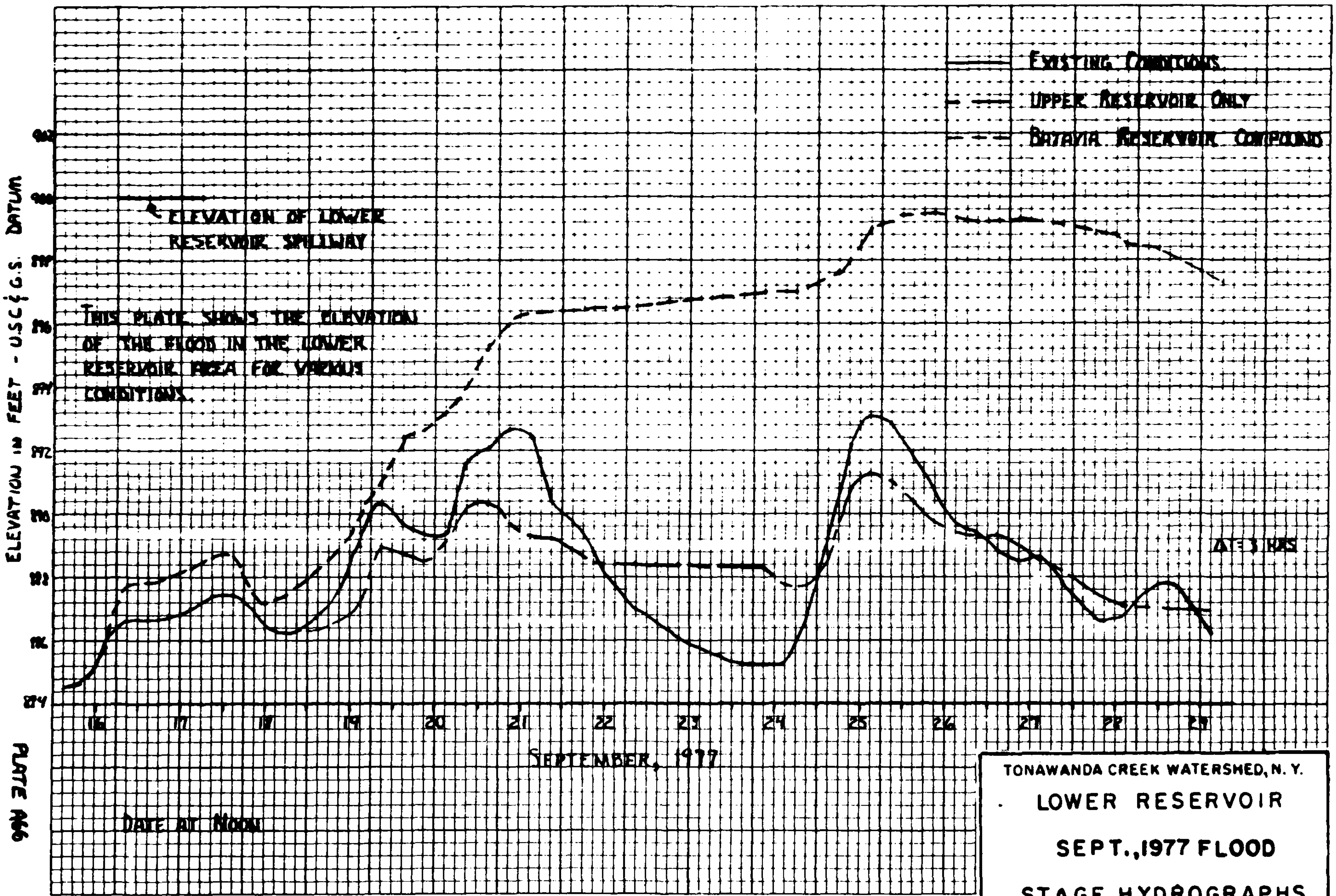
LOWER RESERVOIR

SEPT., 1977 FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A65



TONAWANDA CREEK WATERSHED, N. Y.

LOWER RESERVOIR

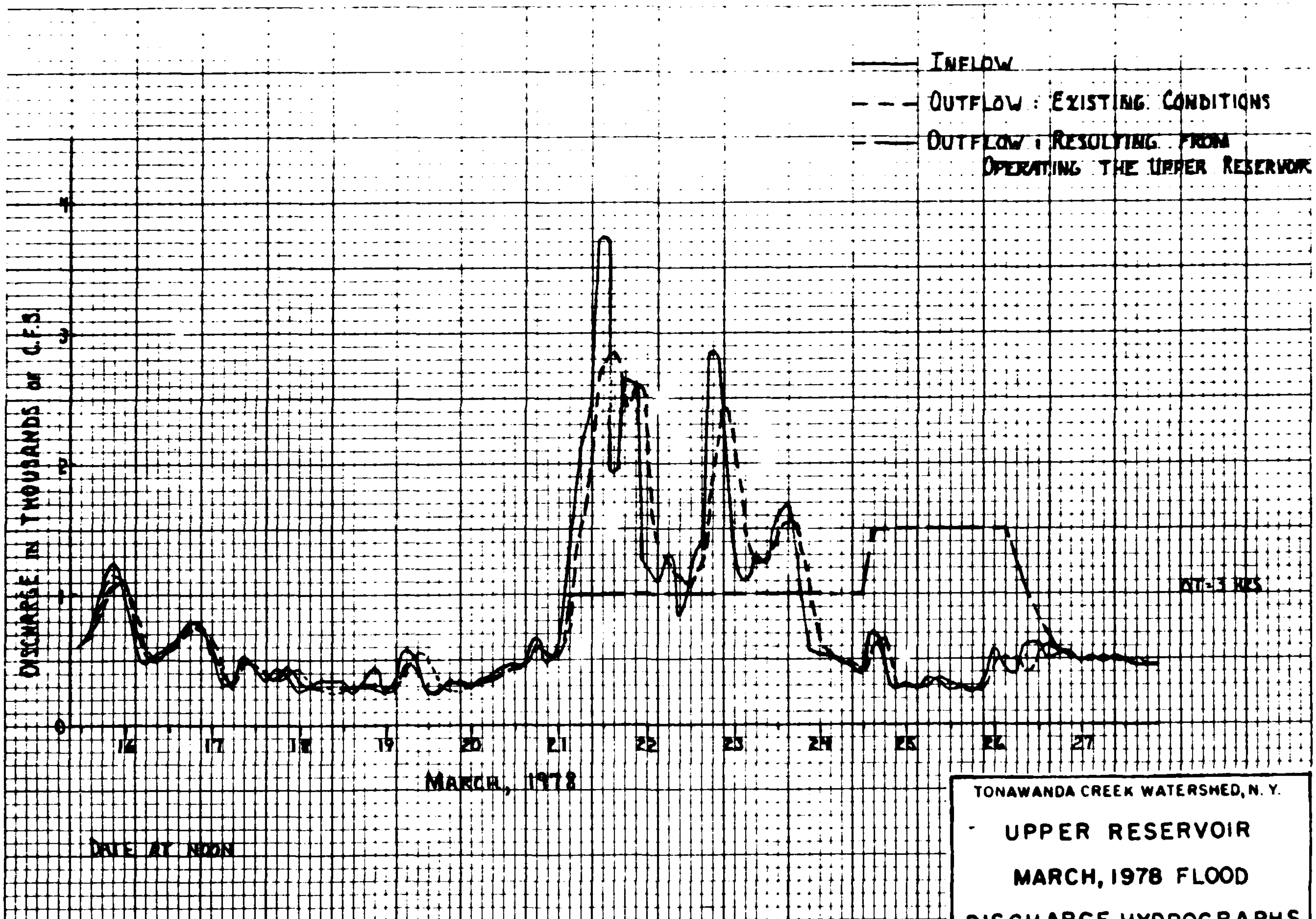
SEPT., 1977 FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A66

K•E 46 1930



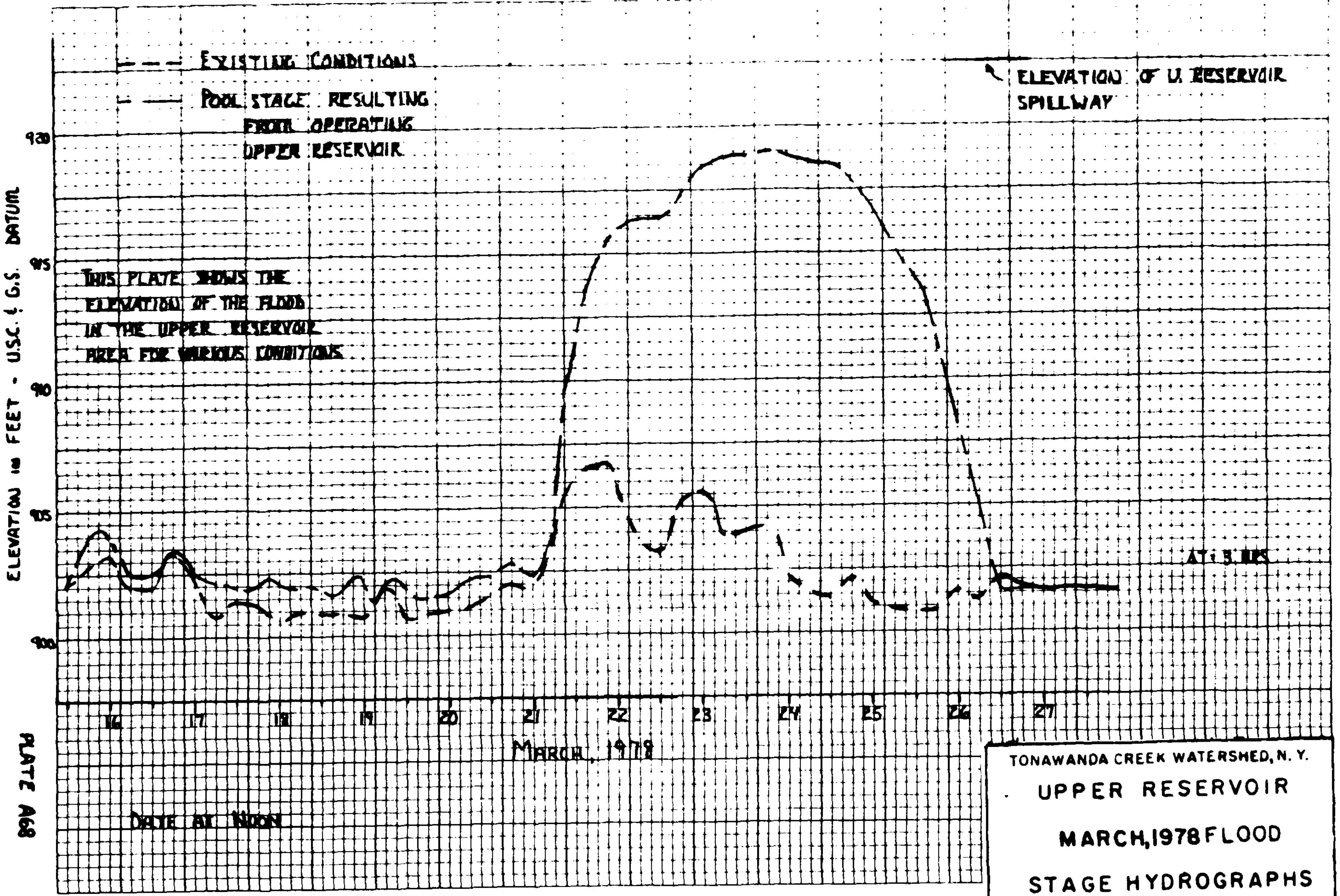
TONAWANDA CREEK WATERSHED, N. Y.

UPPER RESERVOIR

MARCH, 1978 FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, N. Y.

UPPER RESERVOIR

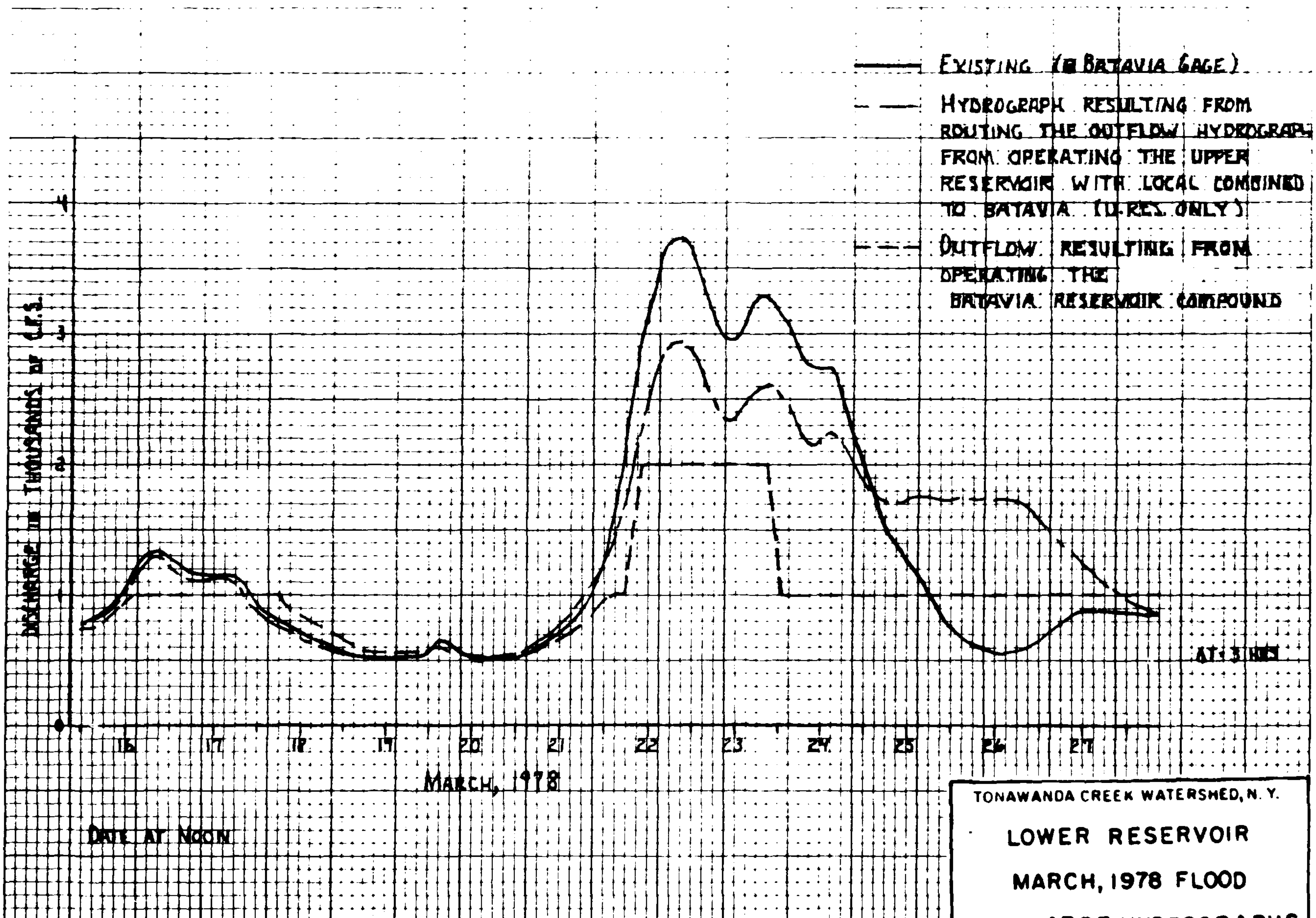
MARCH, 1978 FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A68

K•E 46 1930



TONAWANDA CREEK WATERSHED, N. Y.

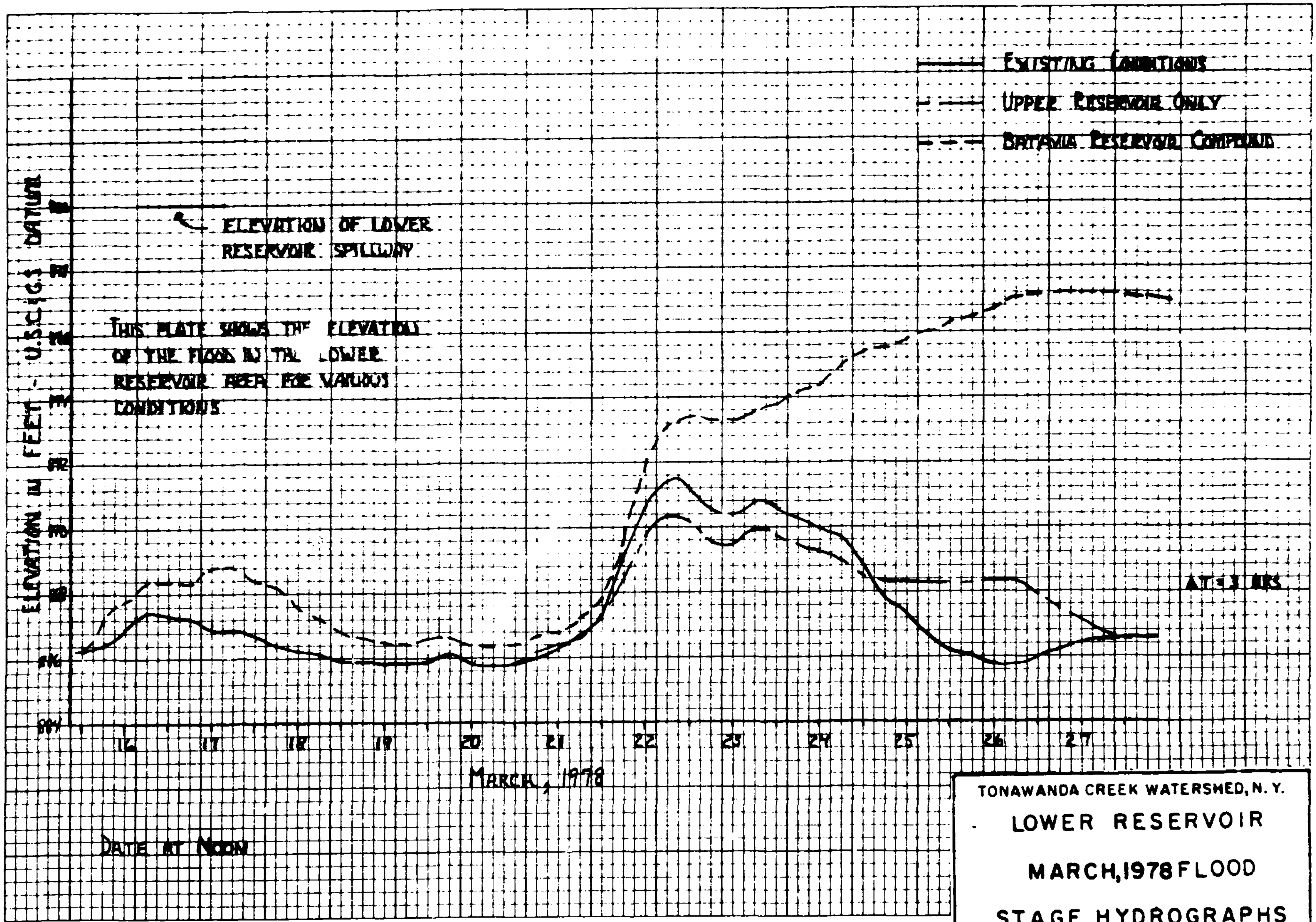
LOWER RESERVOIR

MARCH, 1978 FLOOD

DISCHARGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A69



TONAWANDA CREEK WATERSHED, N. Y.

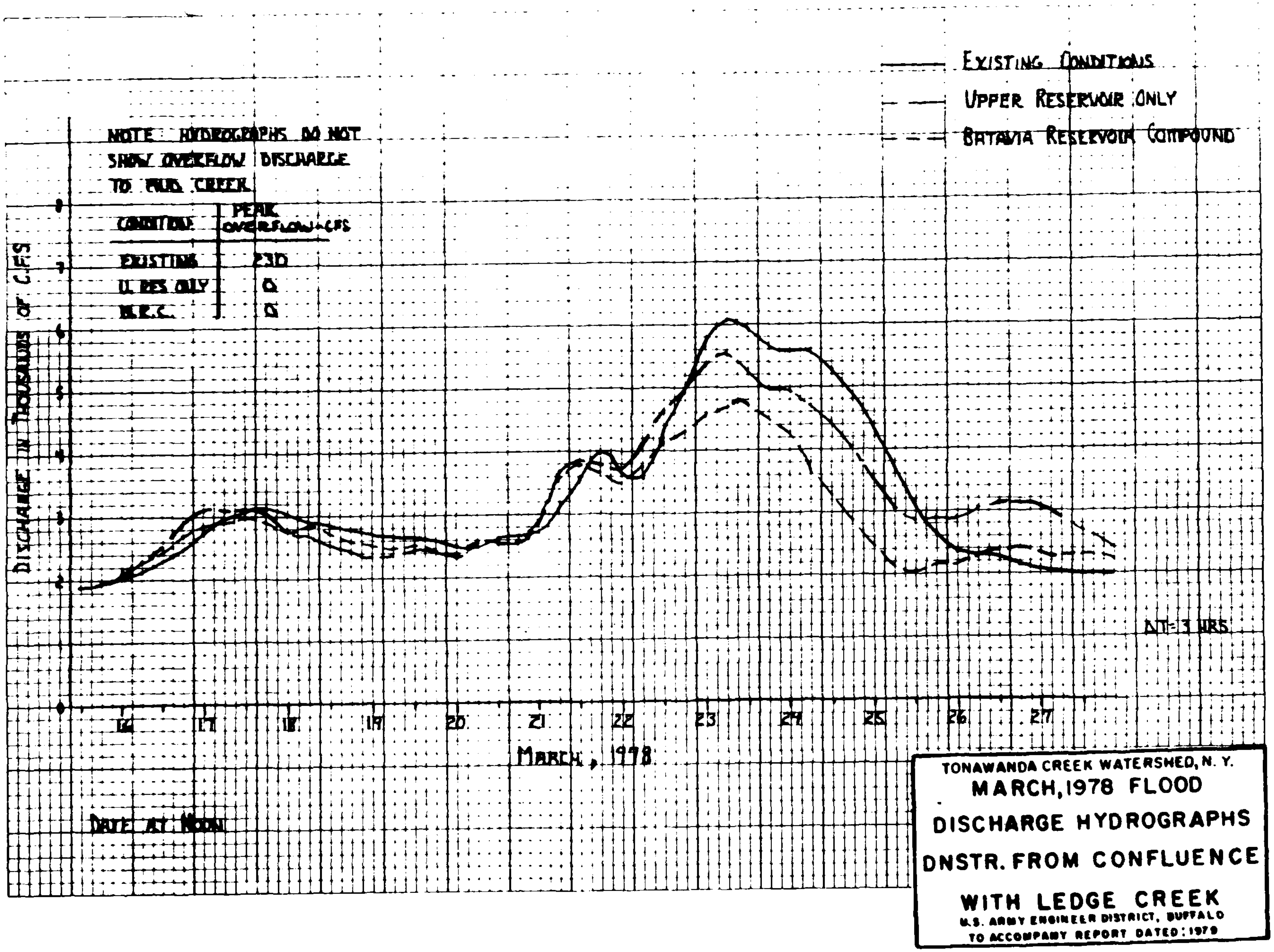
LOWER RESERVOIR

MARCH, 1978 FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A70



EXISTING CONDITIONS
UPPER RESERVOIR ONLY
BATAVIA RESERVOIR COMPOUND
NOTE: HYDROGRAPHS DO NOT SHOW OVERFLOW DISCHARGE TO MUD CREEK
CONDITIONS | PEAK OVERFLOW - CFS
EXISTING | 230
U. RES ONLY | 0
B.R.C. | 0
DISCHARGE IN THOUSANDS OF C.F.S.
0
2
3
4
5
6
7
8
16
17
18
19
20
21
22
23
24
25
26
27
MARCH, 1978
DATE AT NOON
ΔT=3 HRS
TONAWANDA CREEK WATERSHED, N. Y.
MARCH, 1978 FLOOD
DISCHARGE HYDROGRAPHS
DNSTR. FROM CONFLUENCE
WITH LEDGE CREEK
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A71

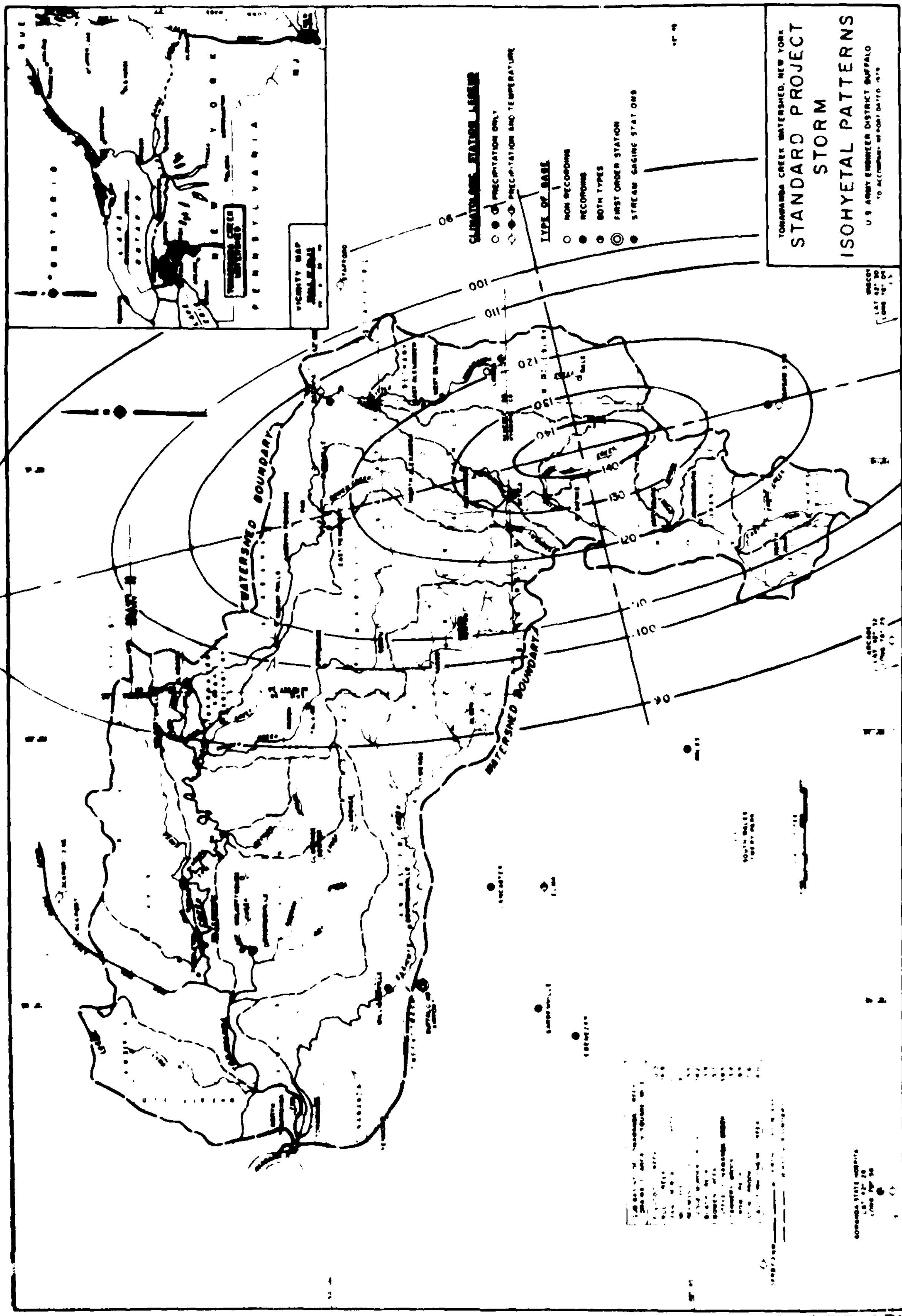
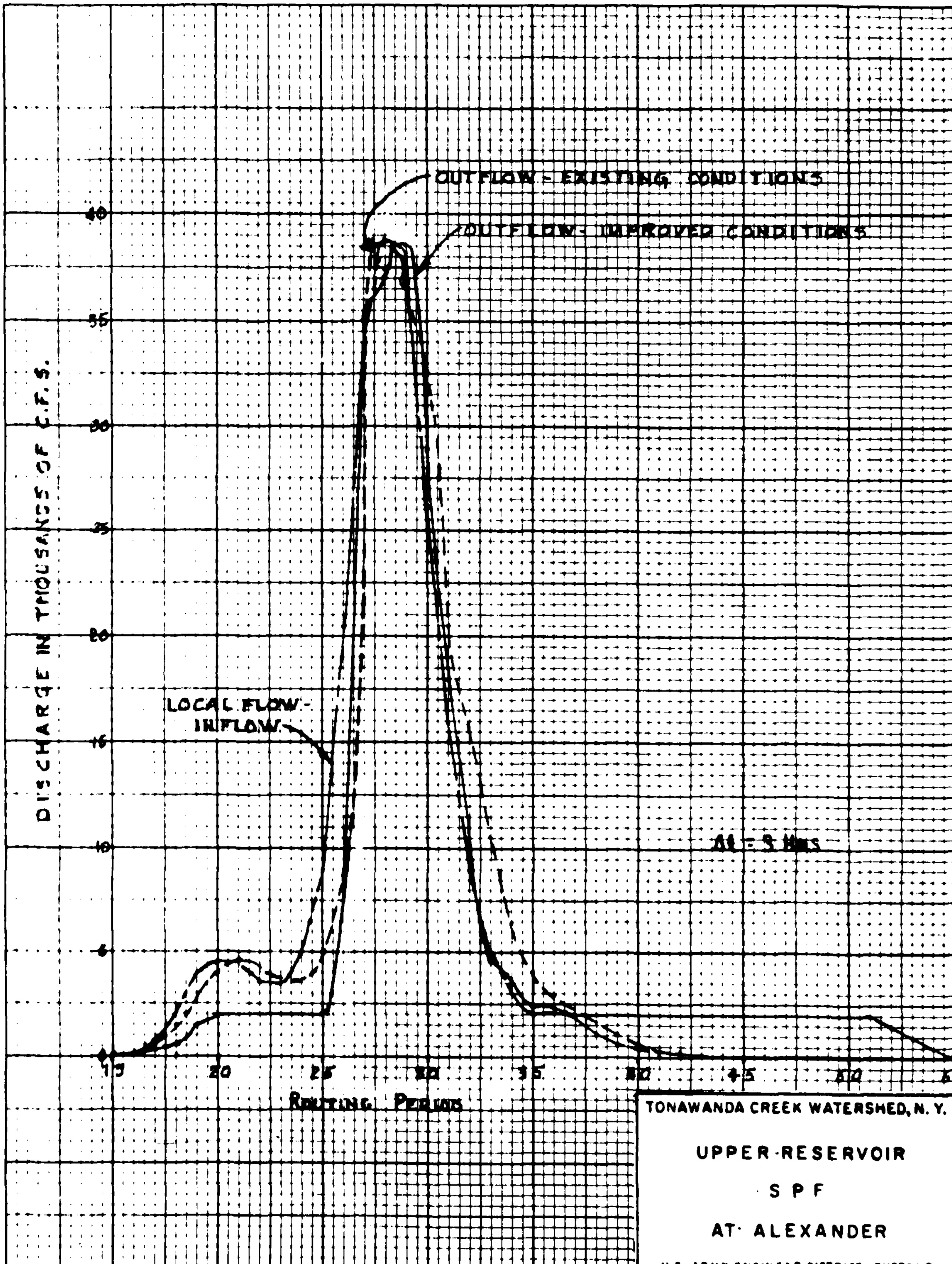

TONAWANDA CREEK WATERSHED, NEW YORK
STANDARD PROJECT
STORM
ISOHYETAL PATTERNS
U.S. ARMY ENGINEER DISTRICT BUFFALO
CLIMATOLOGIC STATION LEGEND
PRECIPITATION ONLY
PRECIPITATION AND TEMPERATURE
TYPE OF GAGE
NON RECORDING
RECORDING
BOTH TYPES
FIRST ORDER STATION
STREAM GAGING STATIONS
WATERSHED BOUNDARY
VICINITY MAP
ONTARIO
PENNSYLVANIA
80
90
100
110
120
130
140

PLATE A71a



TONAWANDA CREEK WATERSHED, N. Y.

UPPER-RESERVOIR

SPF

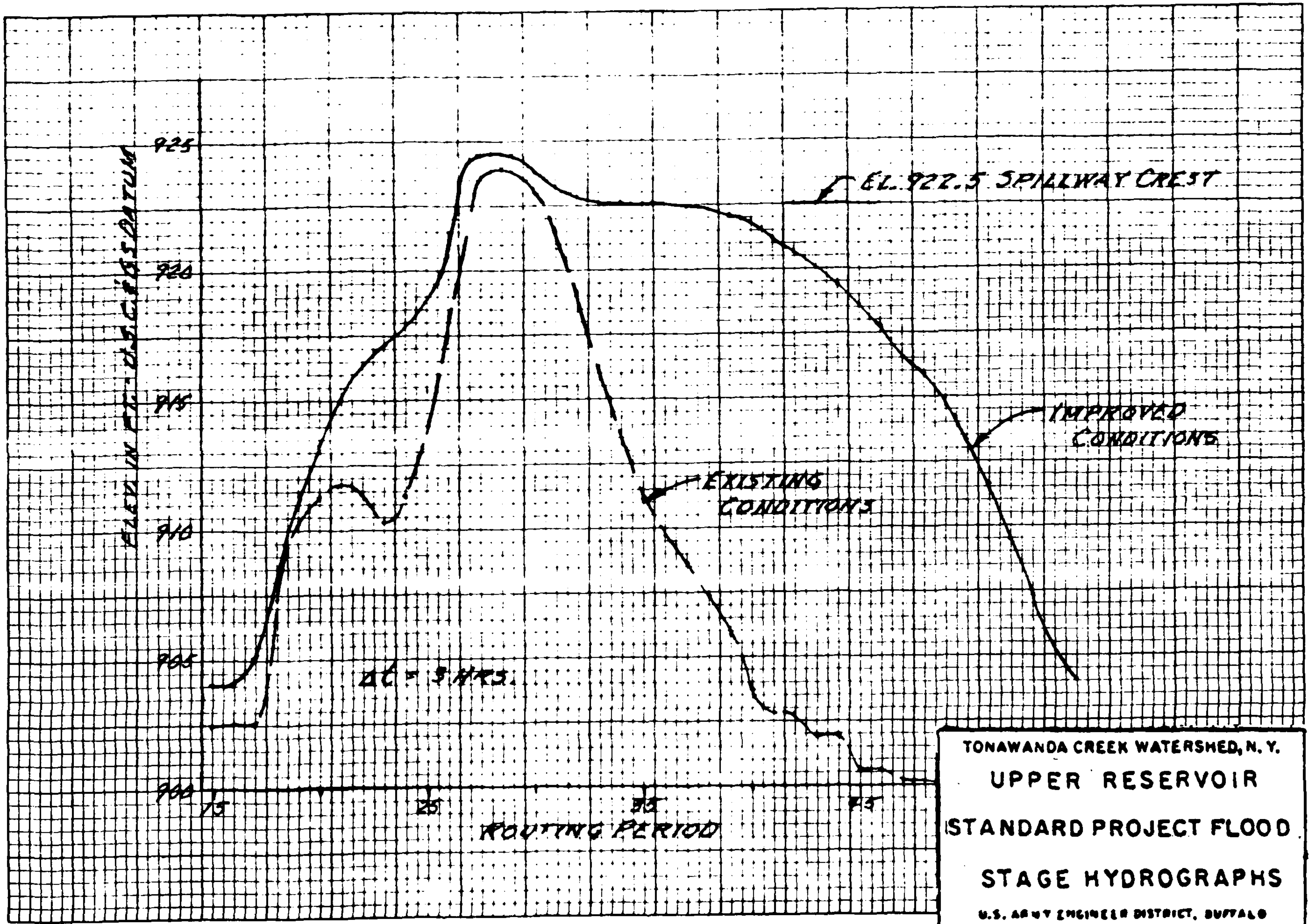
AT ALEXANDER

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A72

46 1020

K-E



TONAWANDA CREEK WATERSHED, N. Y.

UPPER RESERVOIR

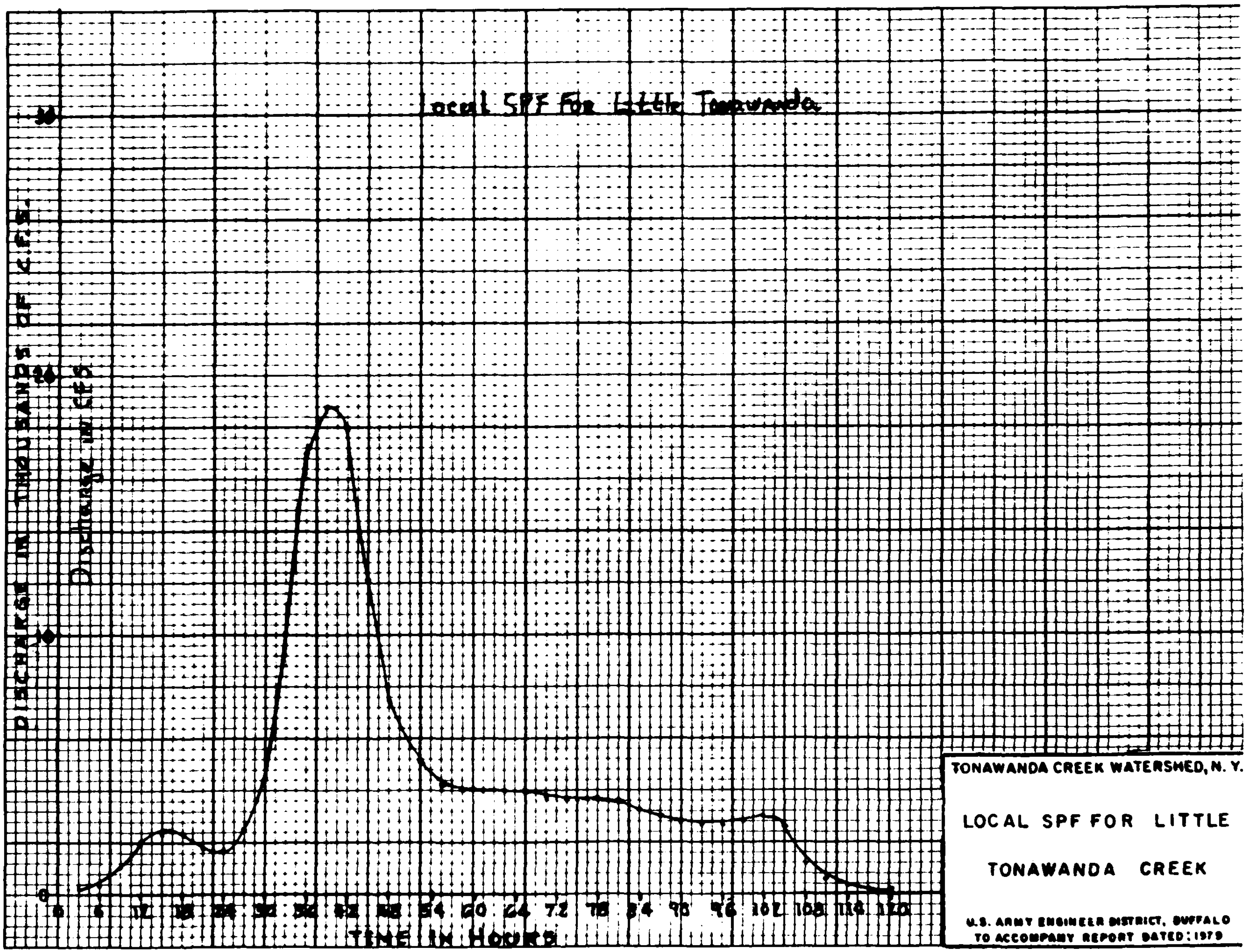
STANDARD PROJECT FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A72a

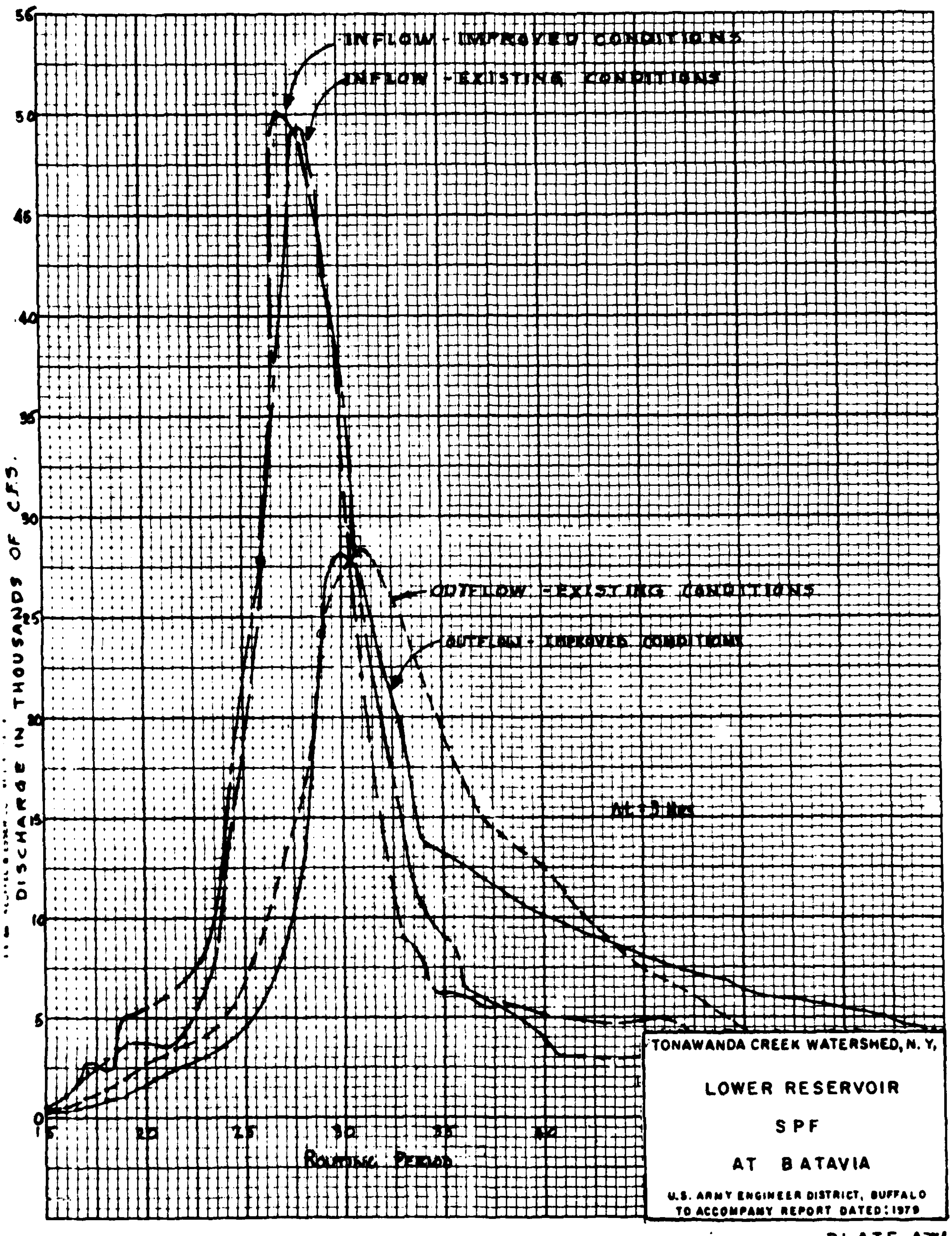
K+E TO 5 6 INCH KEUFFEL & ESSER CO. 46 1020



TONAWANDA CREEK WATERSHED, N. Y.

LOCAL SPF FOR LITTLE TONAWANDA CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, N. Y.

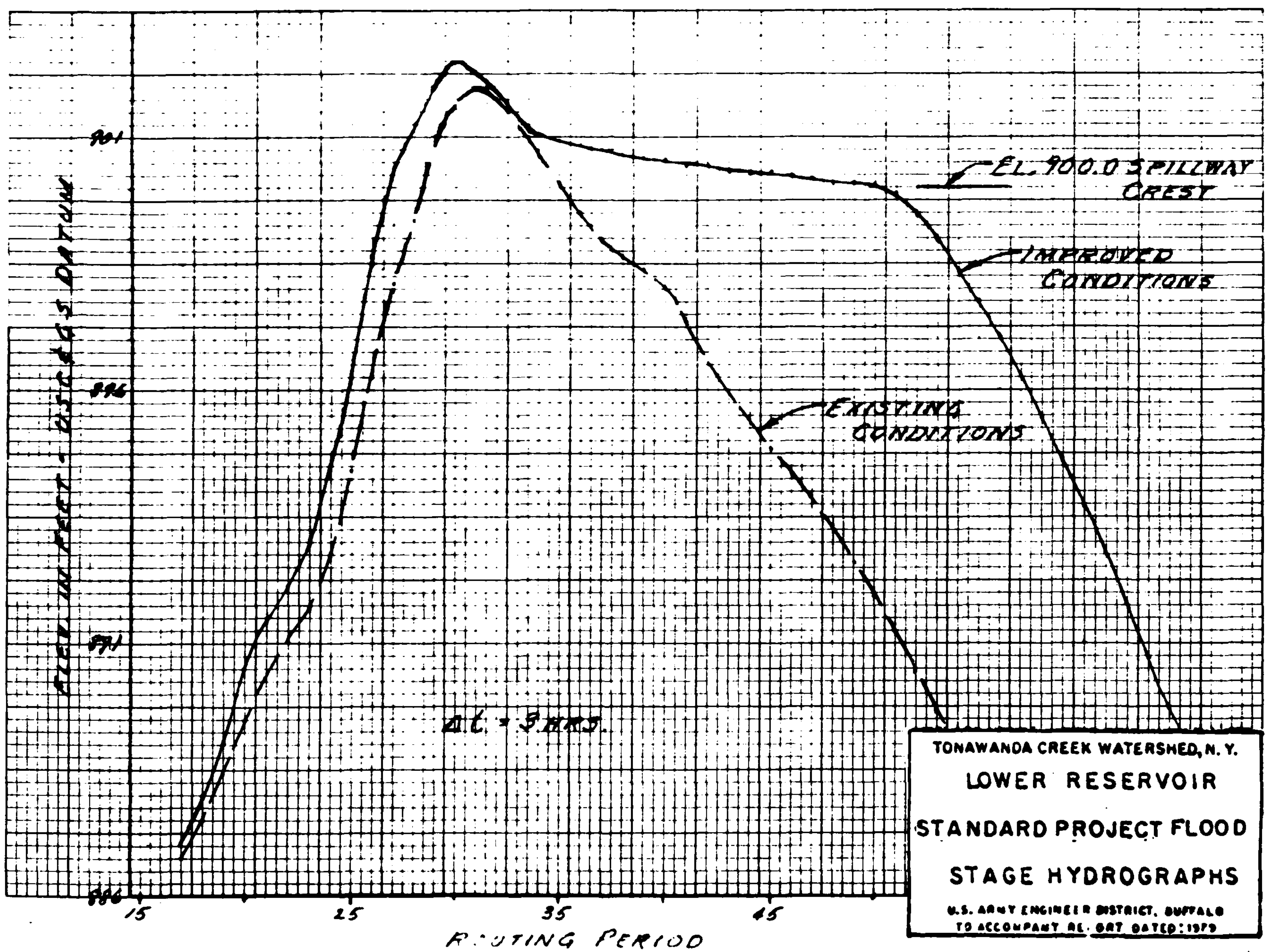
LOWER RESERVOIR

SPF

AT BATAVIA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A74



TONAWANDA CREEK WATERSHED, N. Y.

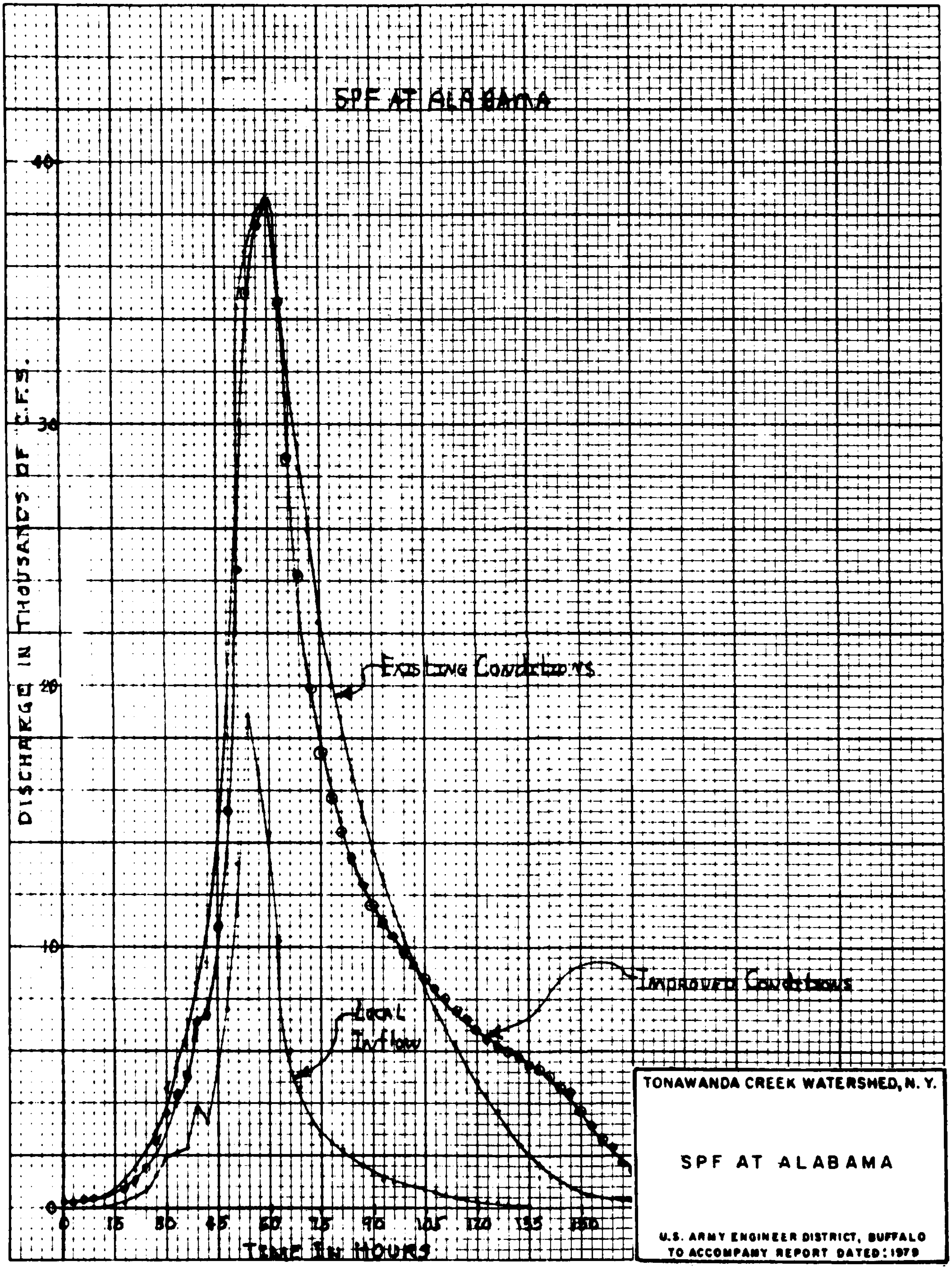
LOWER RESERVOIR

STANDARD PROJECT FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A74a



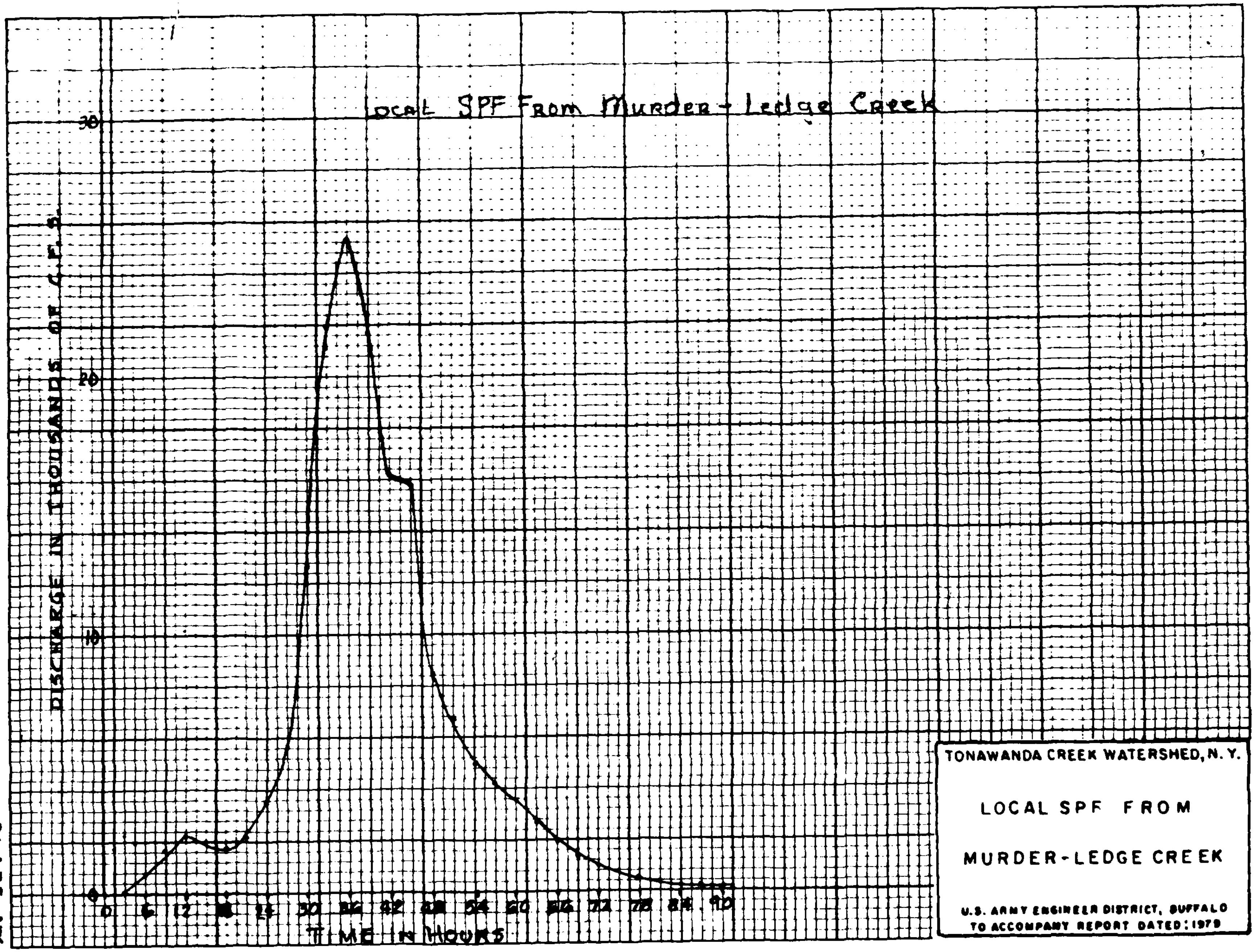
TONAWANDA CREEK WATERSHED, N. Y.

SPF AT ALABAMA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A75

K•E 46 1020



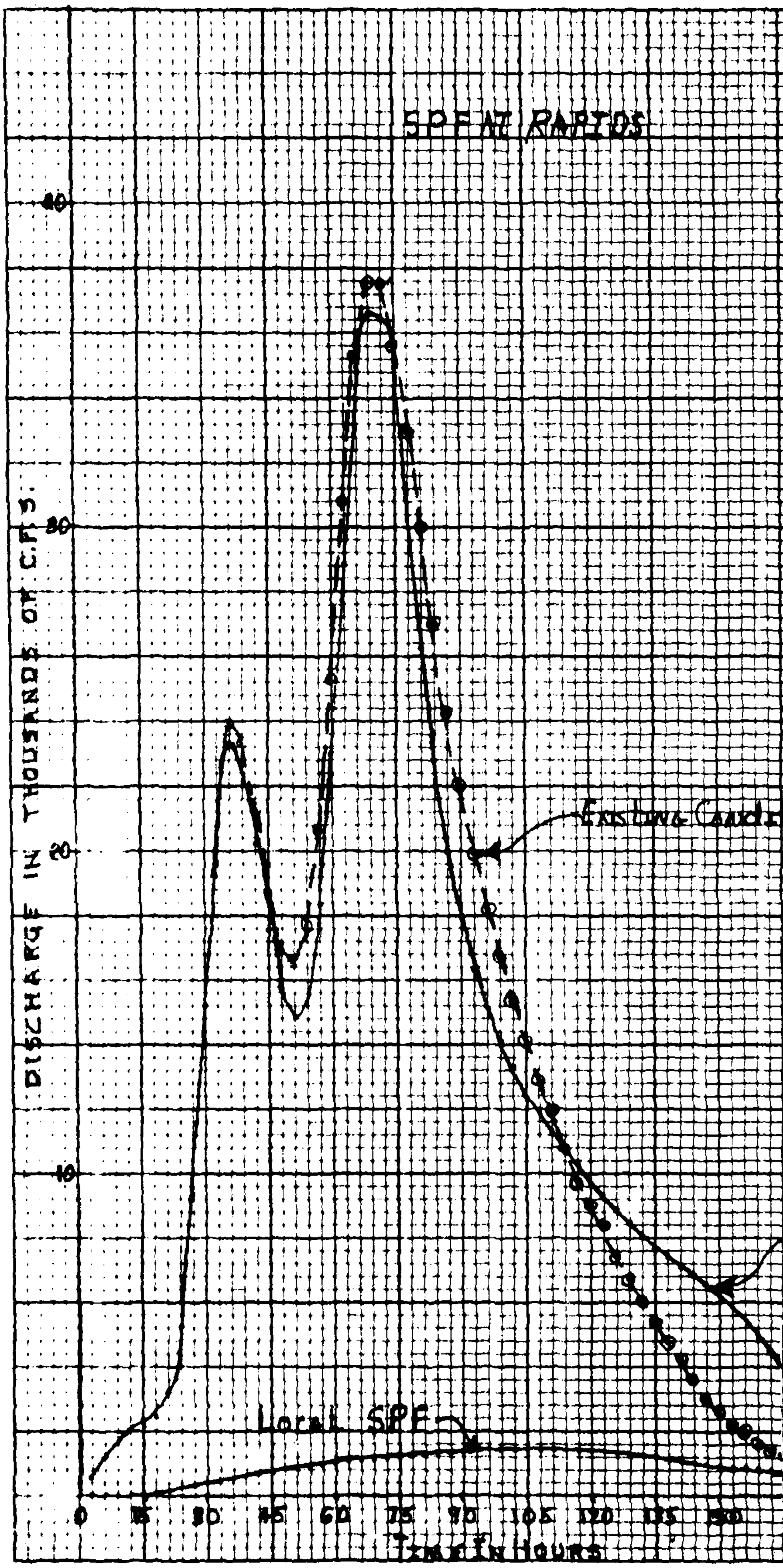
TONAWANDA CREEK WATERSHED, N. Y.

LOCAL SPF FROM

MURDER-LEDGE CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

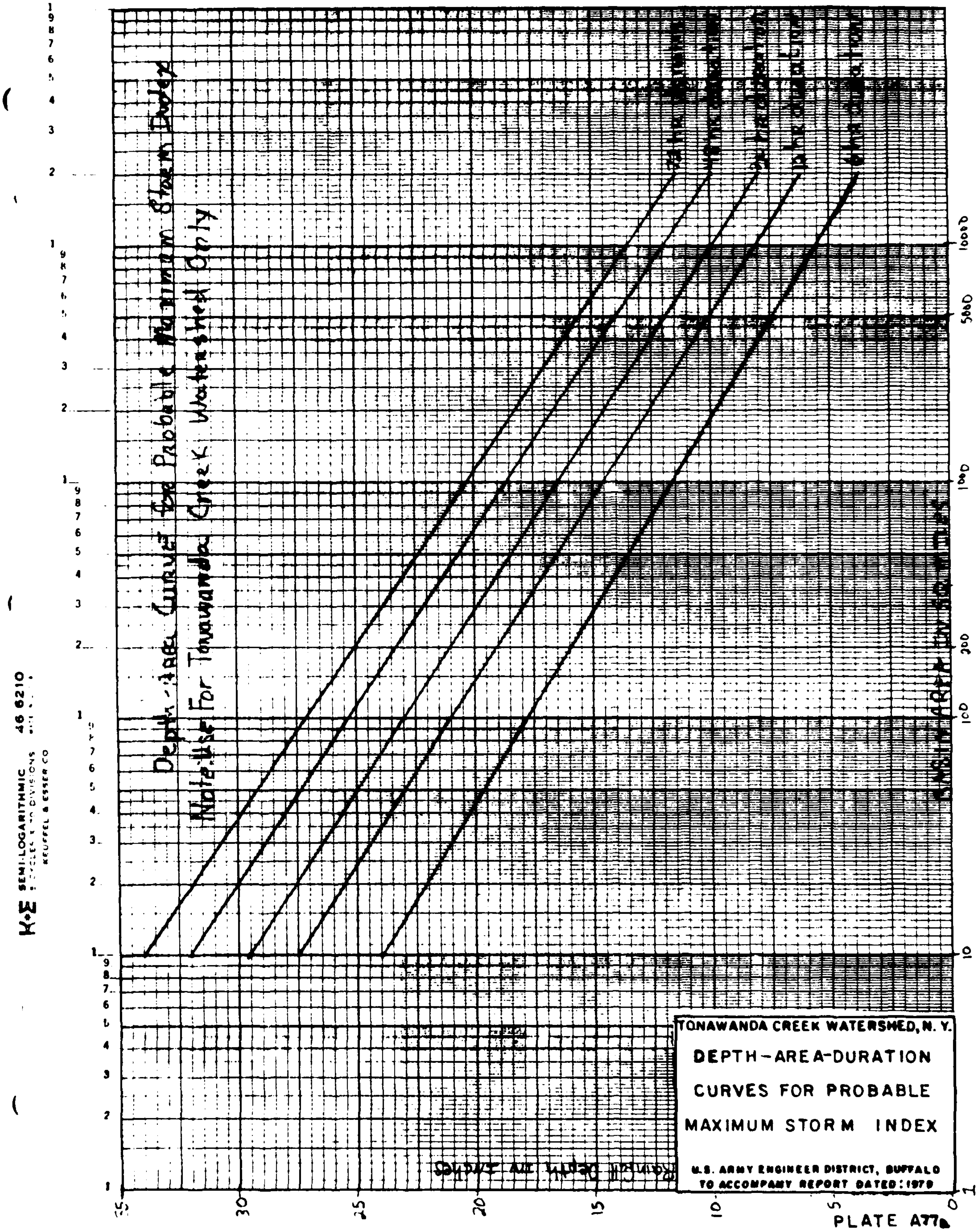
PLATE A76



TONAWANDA CREEK WATERSHED, N. Y.

SPF AT RAPIDS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

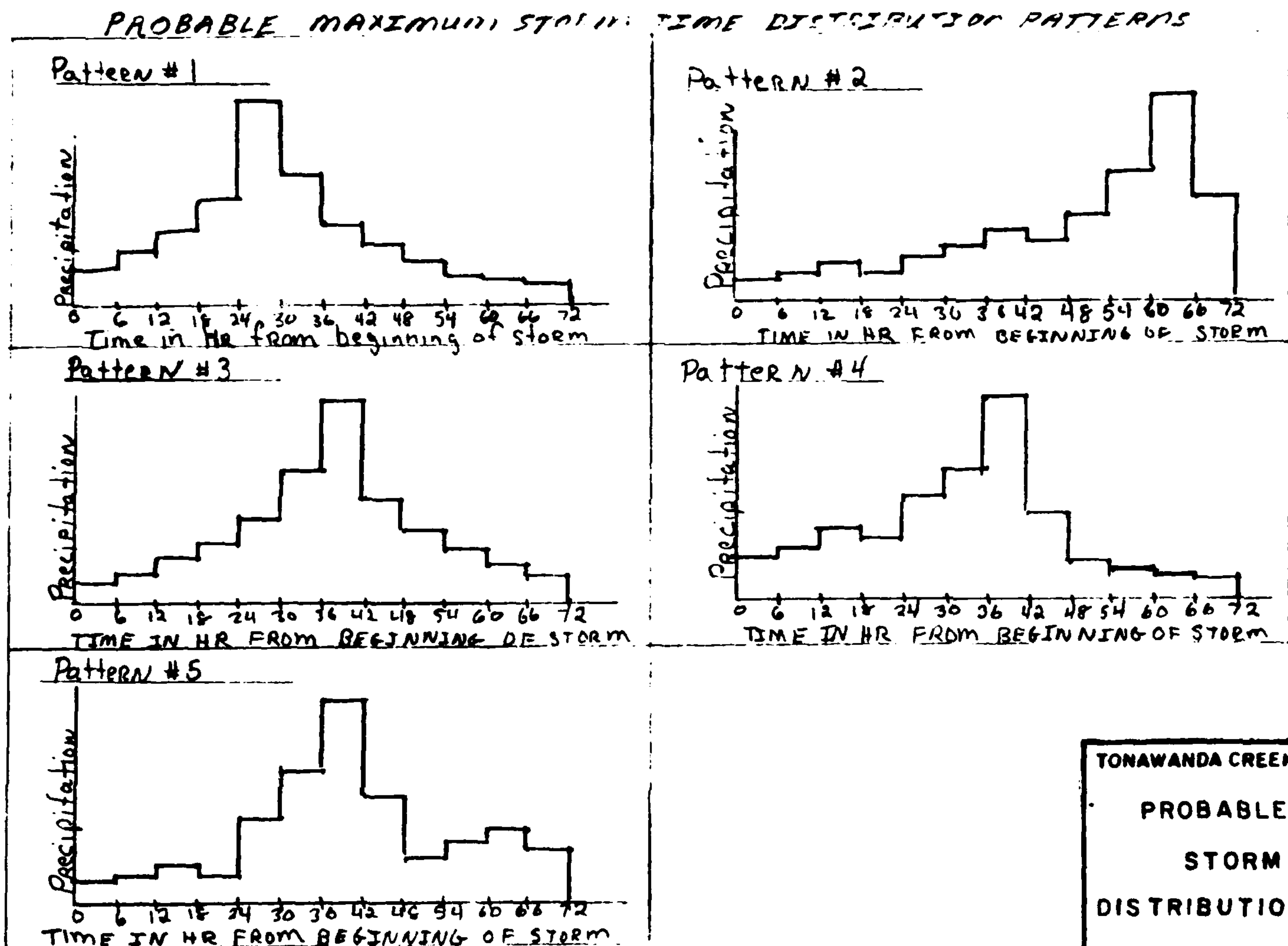


TONAWANDA CREEK WATERSHED, N. Y.

DEPTH-AREA-DURATION CURVES FOR PROBABLE MAXIMUM STORM INDEX

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A77



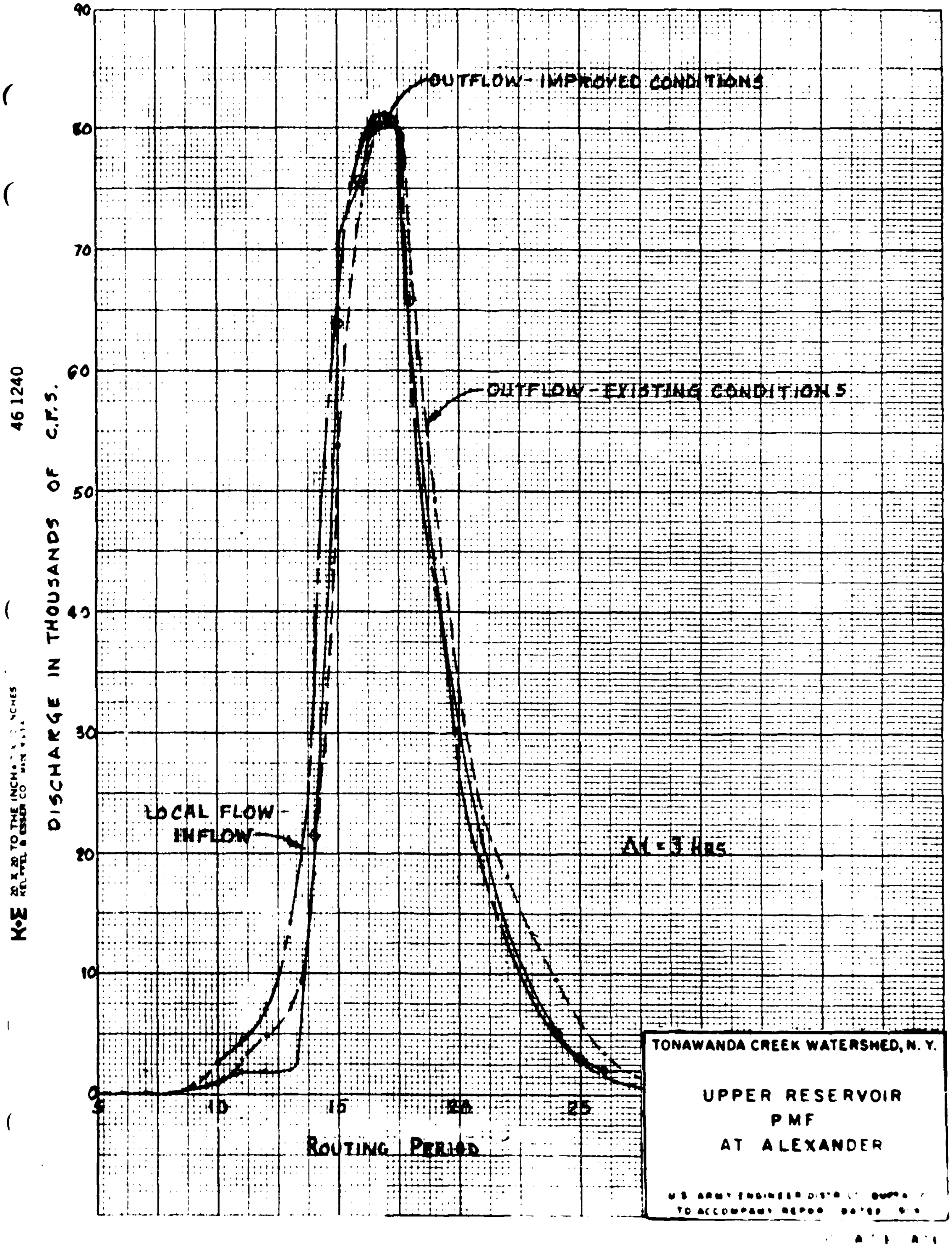
TONAWANDA CREEK WATERSHED, N. Y.

PROBABLE MAXIMUM

STORM TIME

DISTRIBUTION PATTERNS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



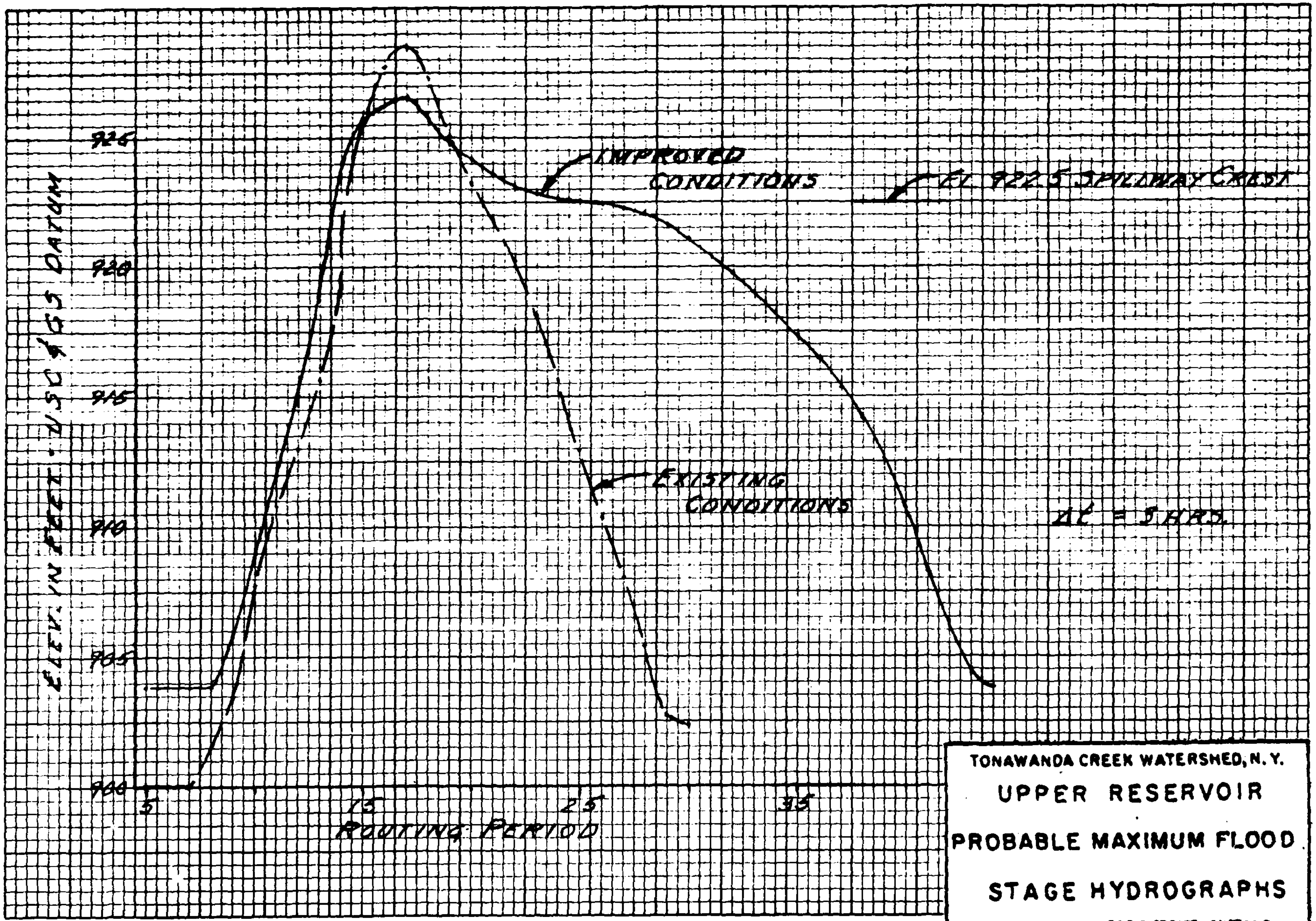
TONAWANDA CREEK WATERSHED, N.Y.

UPPER RESERVOIR
PMF
AT ALEXANDER

AD-A101 439 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2
BUFFALO METROPOLITAN AREA, NEW YORK WATER RESOURCES MANAGEMENT --ETC(U)
1980

UNCLASSIFIED NL

AD
A101439



TONAWANDA CREEK WATERSHED, N.Y.

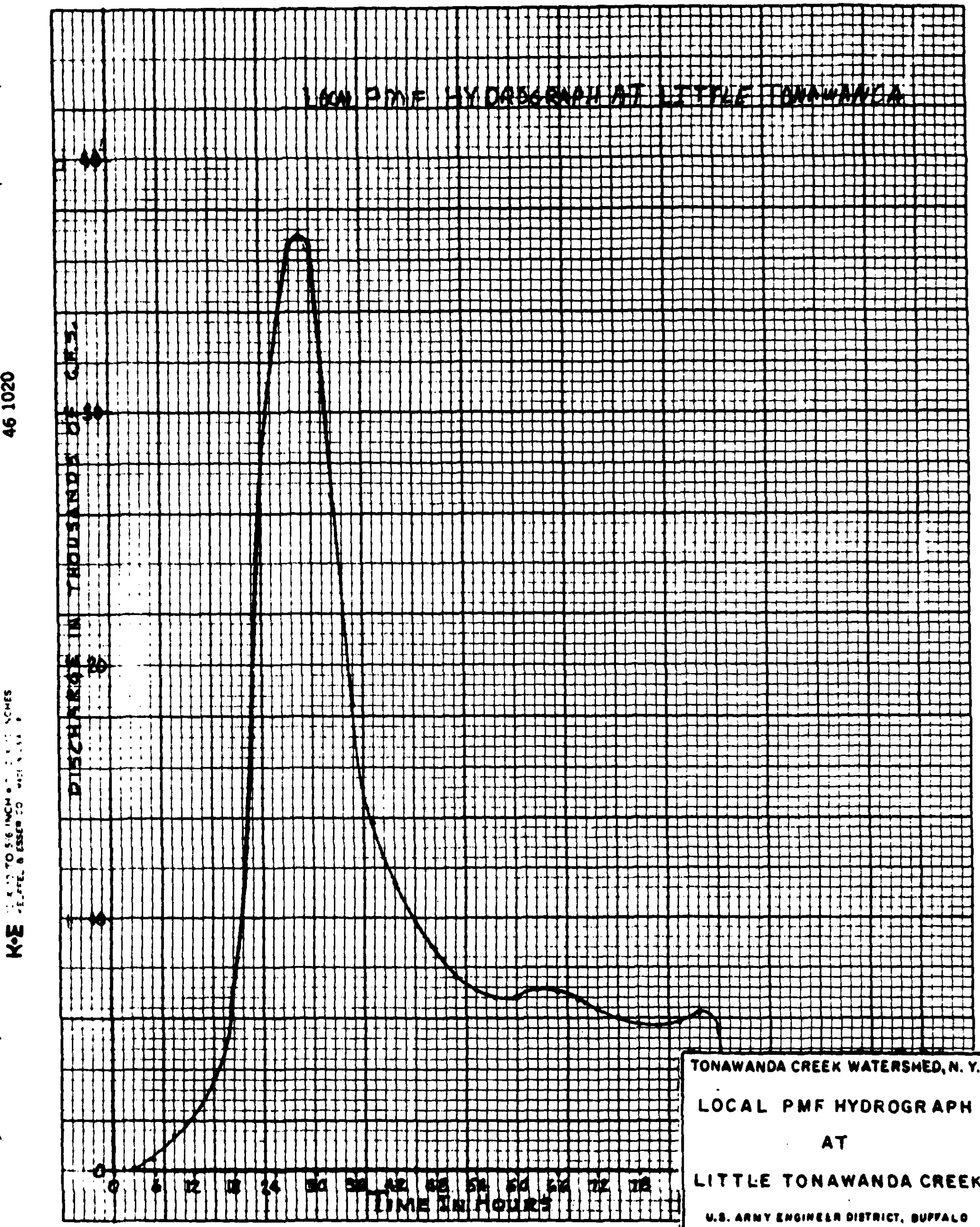
UPPER RESERVOIR

PROBABLE MAXIMUM FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A78a

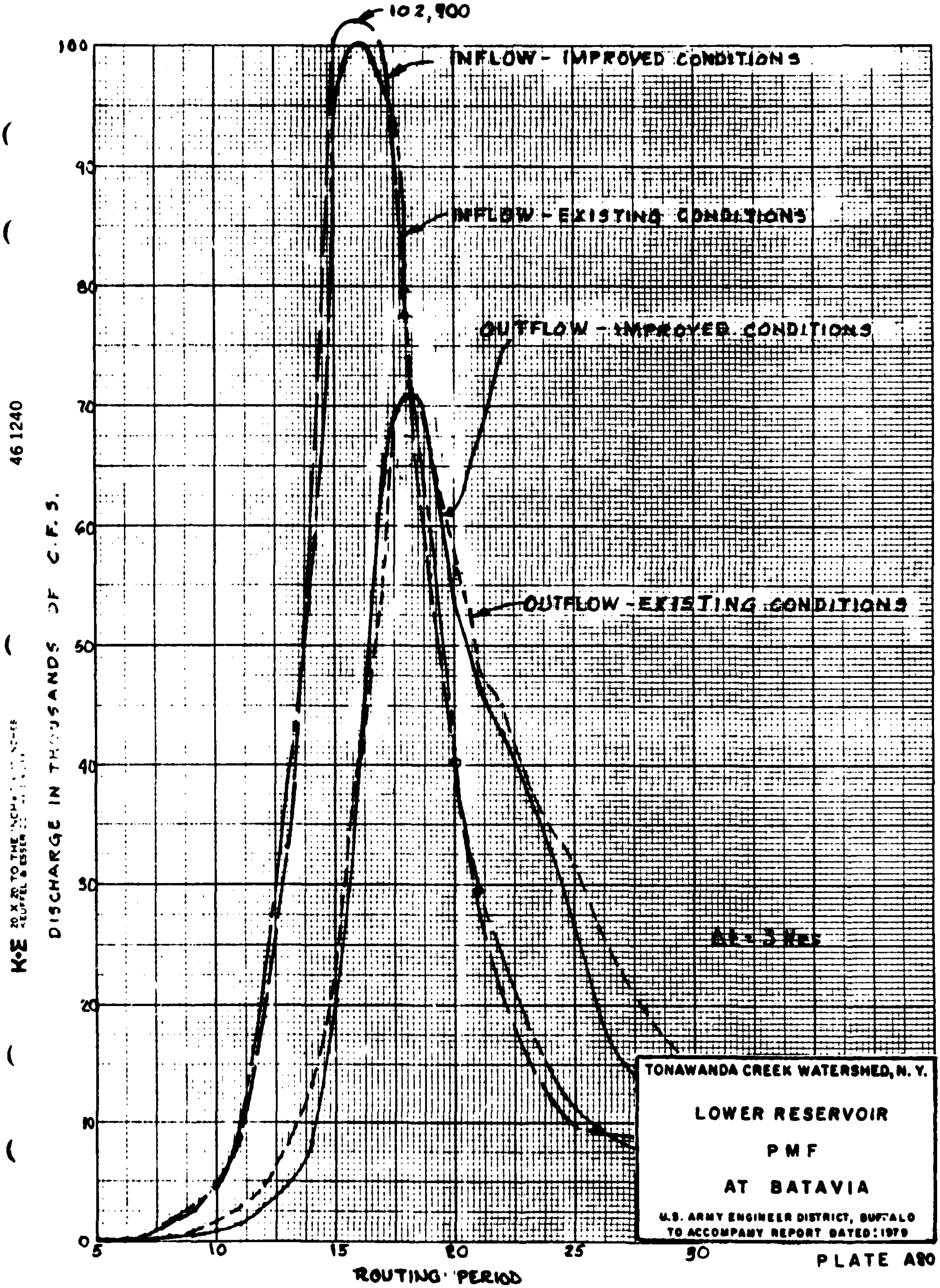


TONAWANDA CREEK WATERSHED, N. Y.

LOCAL PMF HYDROGRAPH
AT
LITTLE TONAWANDA CREEK

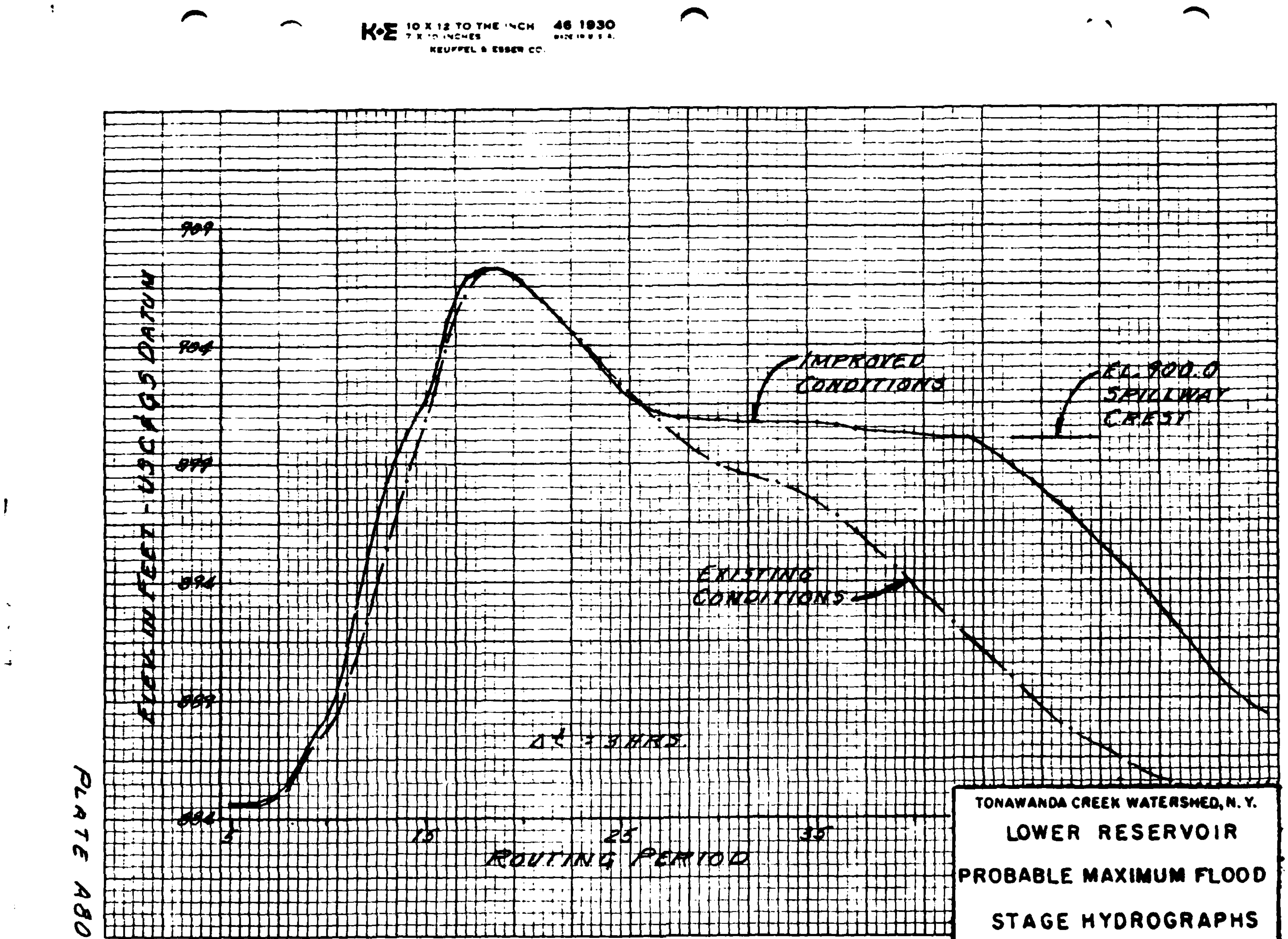
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A79



102,900
INFLOW - IMPROVED CONDITIONS
INFLOW - EXISTING CONDITIONS
OUTFLOW - IMPROVED CONDITIONS
OUTFLOW - EXISTING CONDITIONS
Δt = 3 Hrs
DISCHARGE IN THOUSANDS OF C.F.S.
ROUTING PERIOD
0
10
20
30
40
50
60
70
80
90
100
5
10
15
20
25
30
TONAWANDA CREEK WATERSHED, N. Y.
LOWER RESERVOIR
PMF
AT BATAVIA
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
K·E 20 X 20 TO THE INCH
KEUFFEL & ESSER
461240

PLATE A80



TONAWANDA CREEK WATERSHED, N. Y.

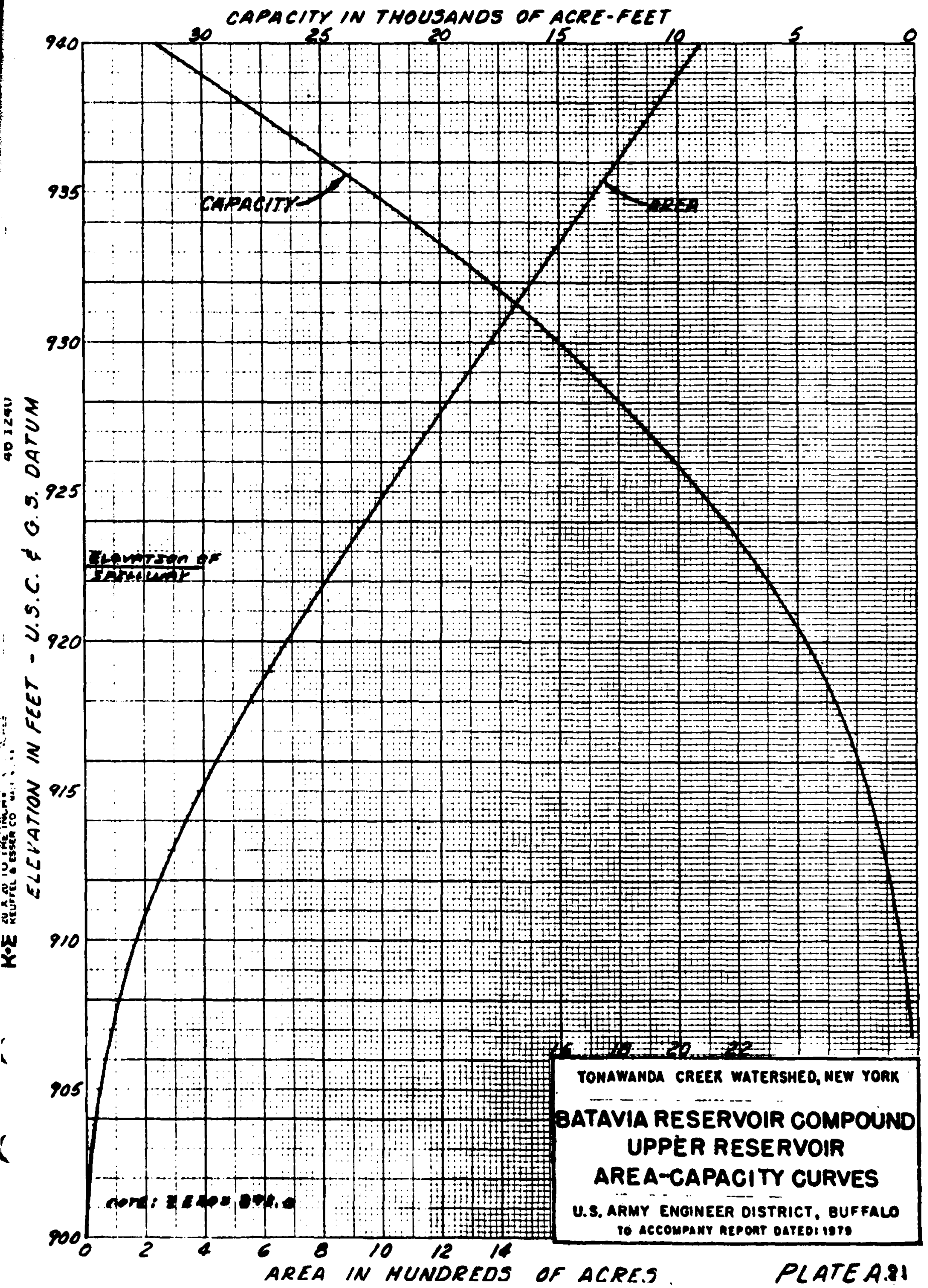
LOWER RESERVOIR

PROBABLE MAXIMUM FLOOD

STAGE HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A80a

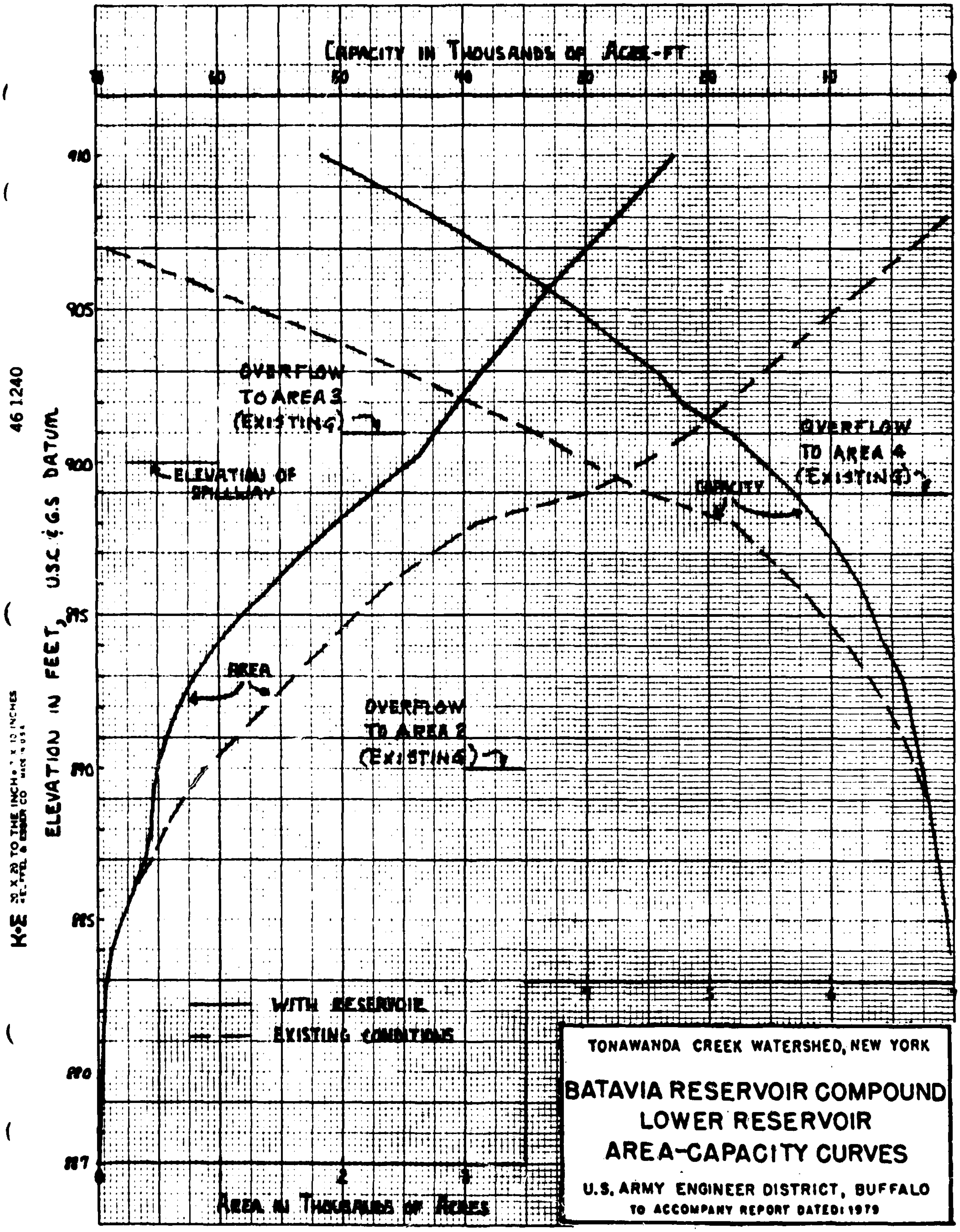


TONAWANDA CREEK WATERSHED, NEW YORK

BATAVIA RESERVOIR COMPOUND
UPPER RESERVOIR
AREA-CAPACITY CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A.21

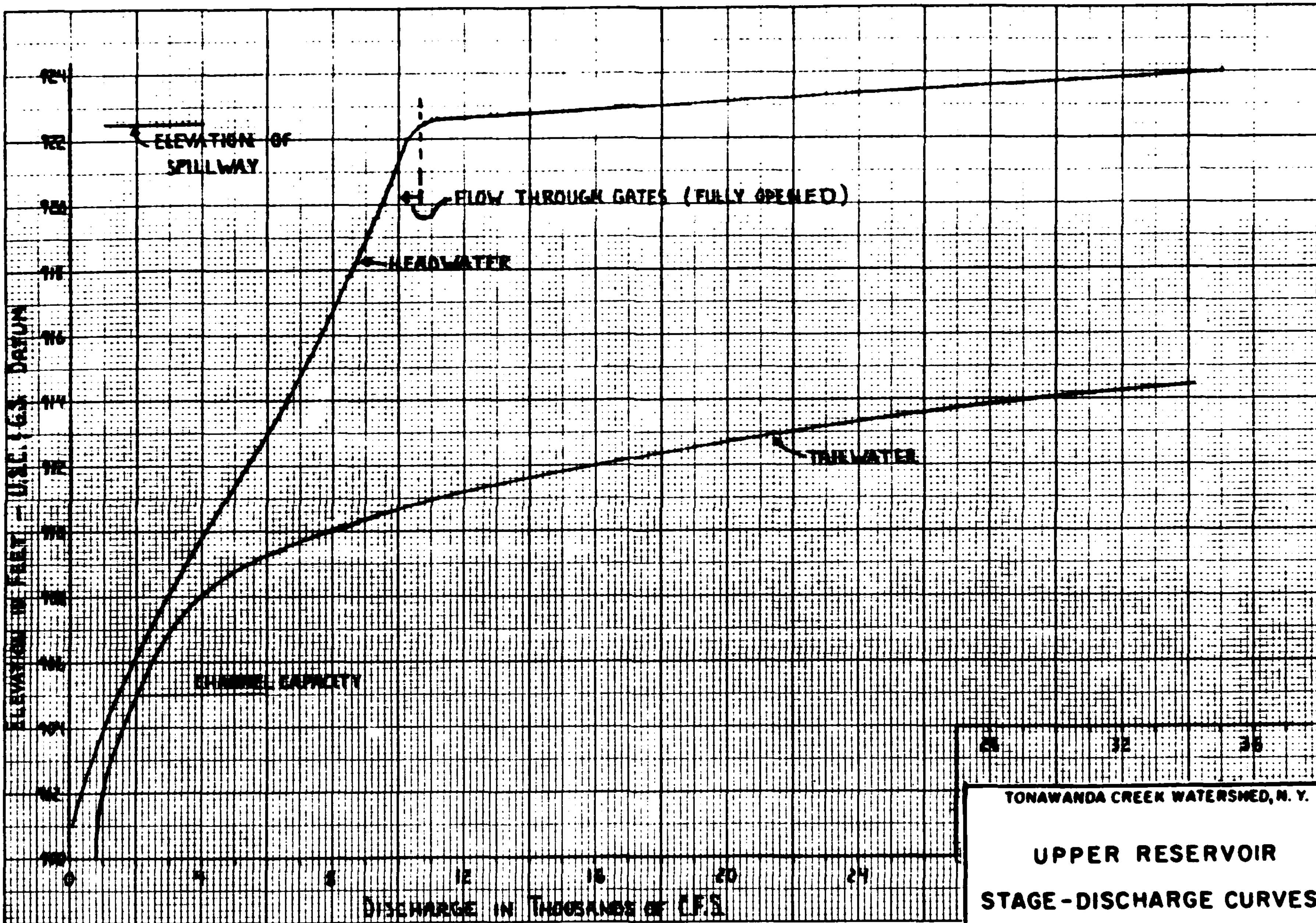


TONAWANDA CREEK WATERSHED, NEW YORK

BATAVIA RESERVOIR COMPOUND
LOWER RESERVOIR
AREA-CAPACITY CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A82



TONAWANDA CREEK WATERSHED, N. Y.

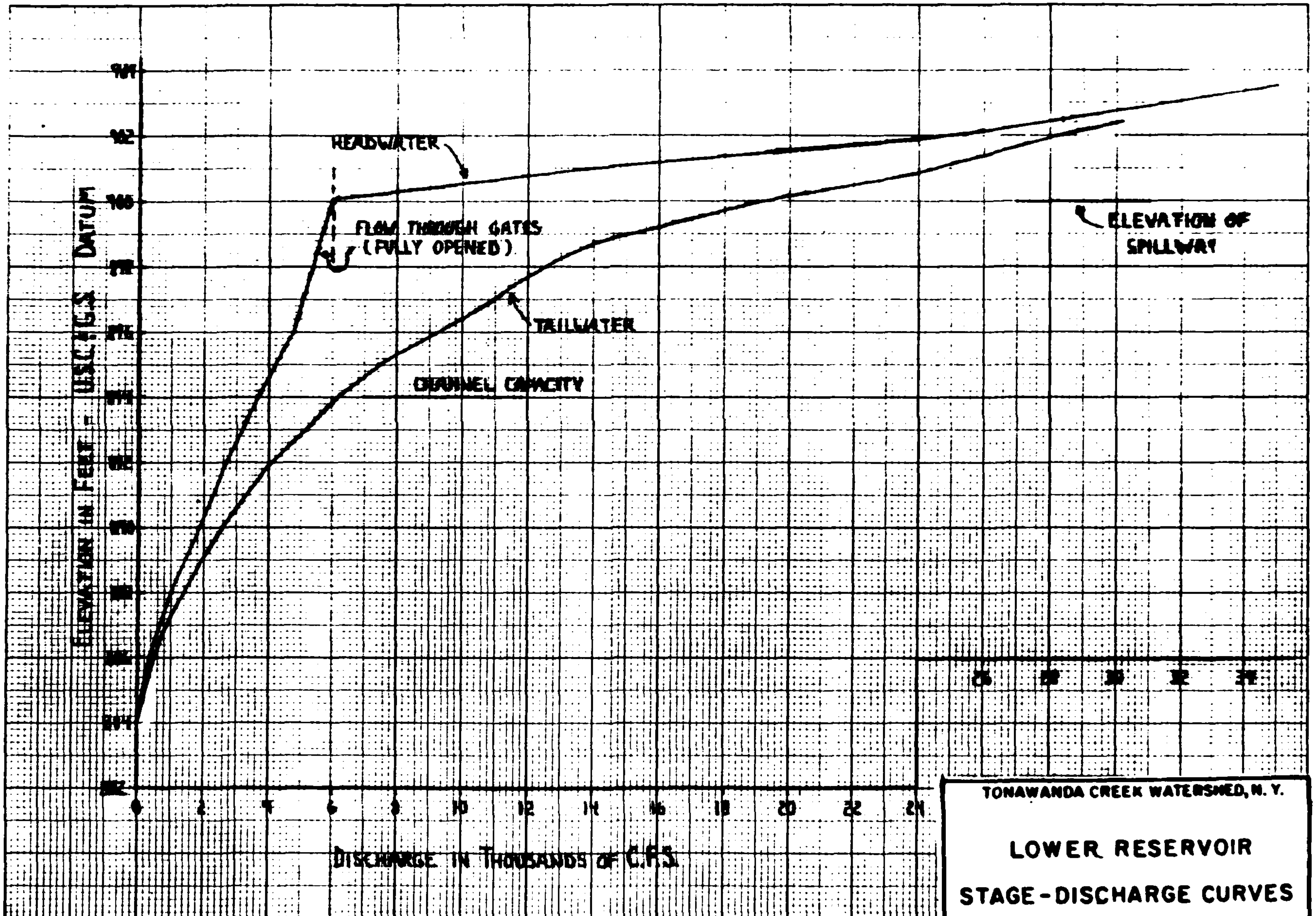
UPPER RESERVOIR

STAGE-DISCHARGE CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A83

K·E 10 X 10 TO THE INCH ... KEUFFEL & ESSER CO. ... 46 1240



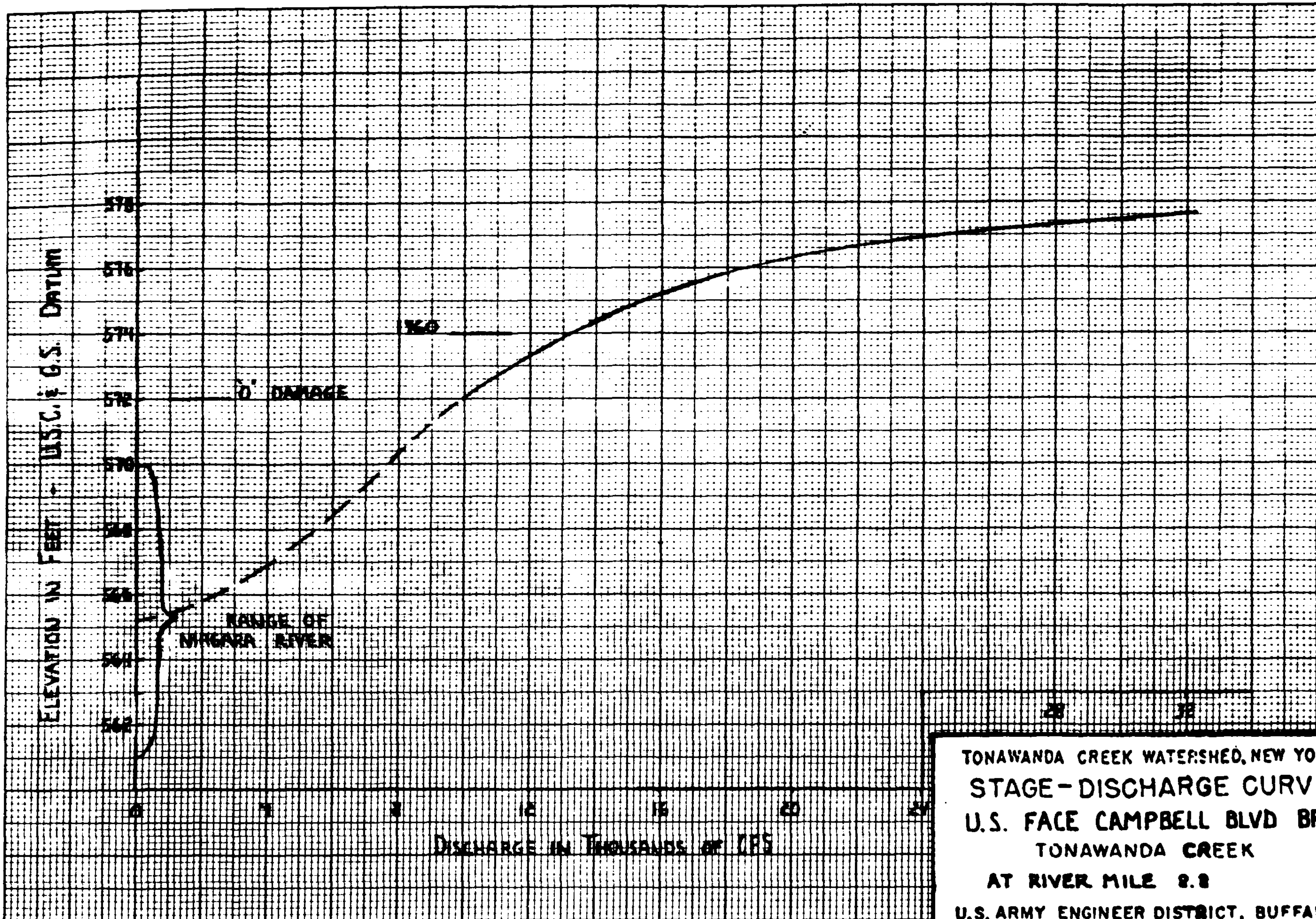
TONAWANDA CREEK WATERSHED, N. Y.

LOWER RESERVOIR

STAGE-DISCHARGE CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A84



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DISCHARGE CURVE

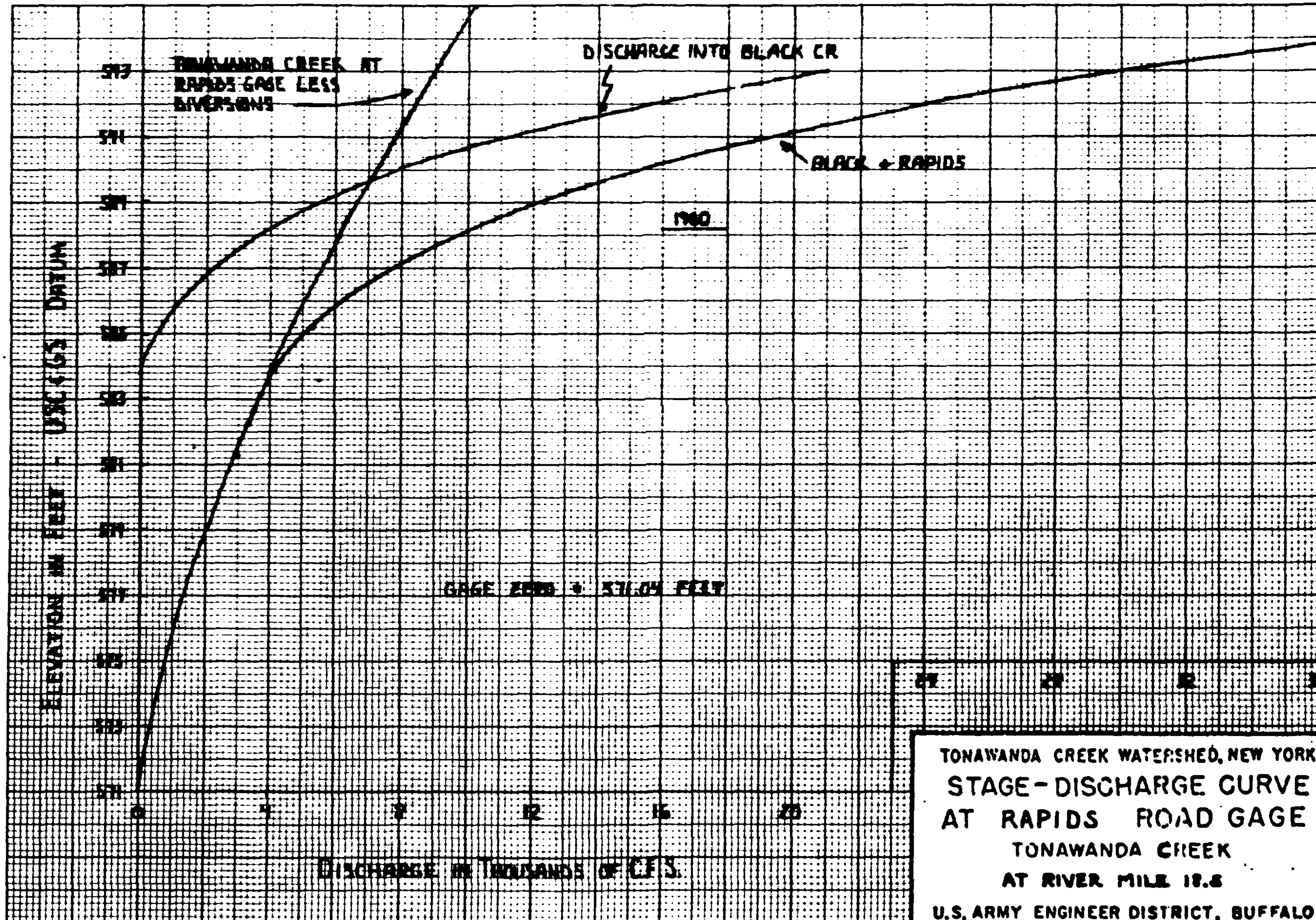
U.S. FACE CAMPBELL BLVD BR.

TONAWANDA CREEK

AT RIVER MILE 2.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



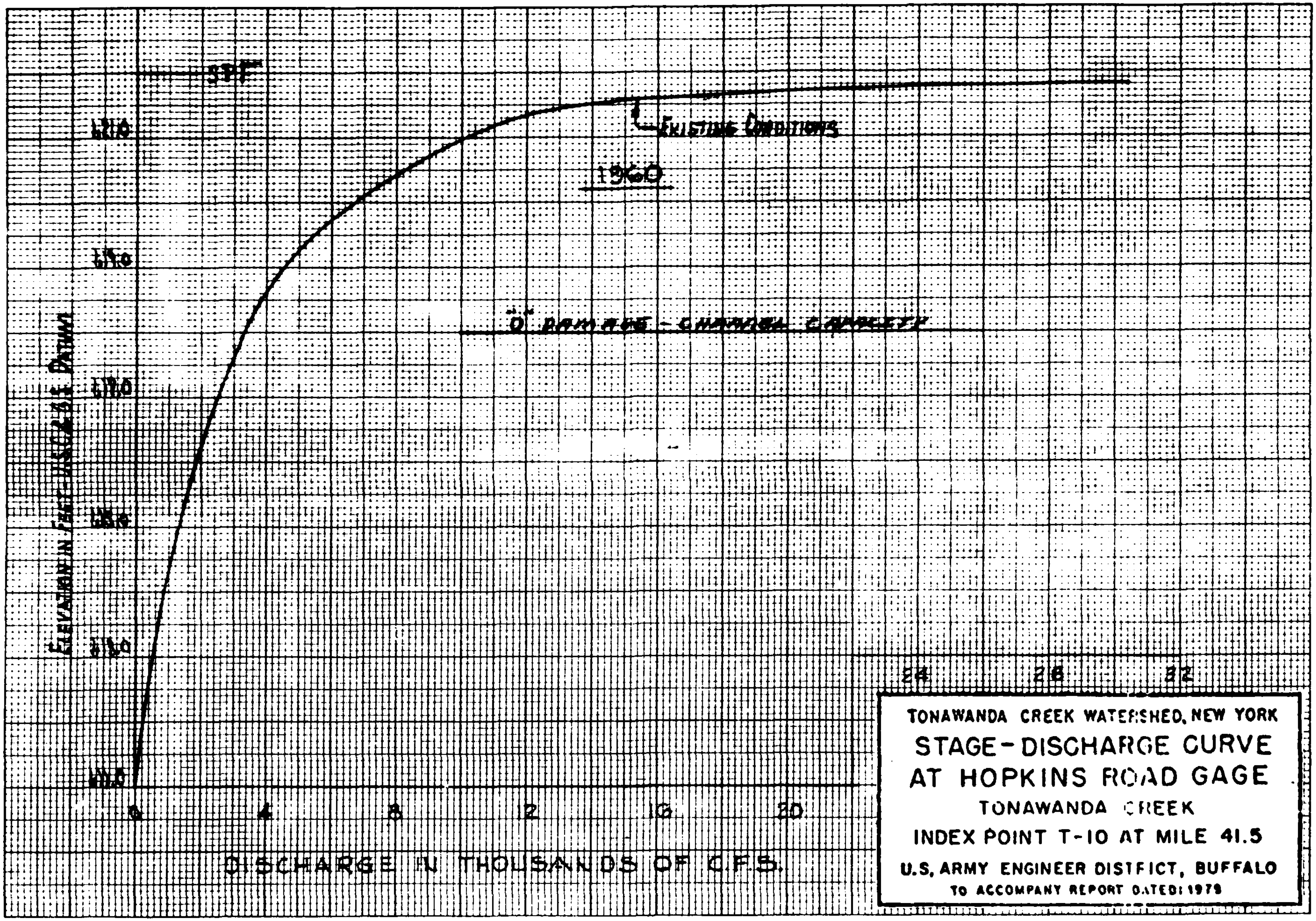
TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DISCHARGE CURVE
AT RAPIDS ROAD GAGE

TONAWANDA CREEK
AT RIVER MILE 18.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DISCHARGE CURVE
AT HOPKINS ROAD GAGE

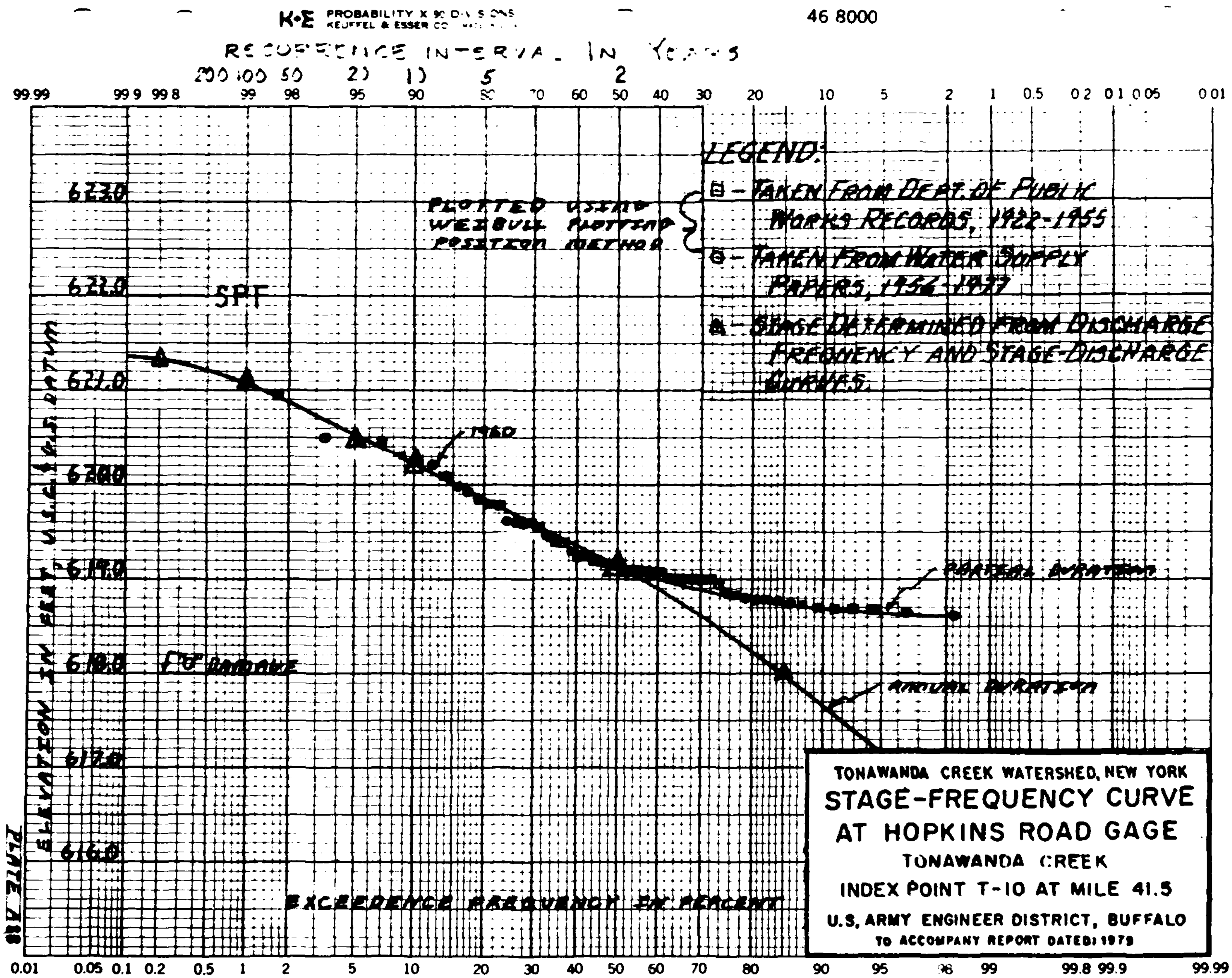
TONAWANDA CREEK

INDEX POINT T-10 AT MILE 41.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A 87



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVE AT HOPKINS ROAD GAGE

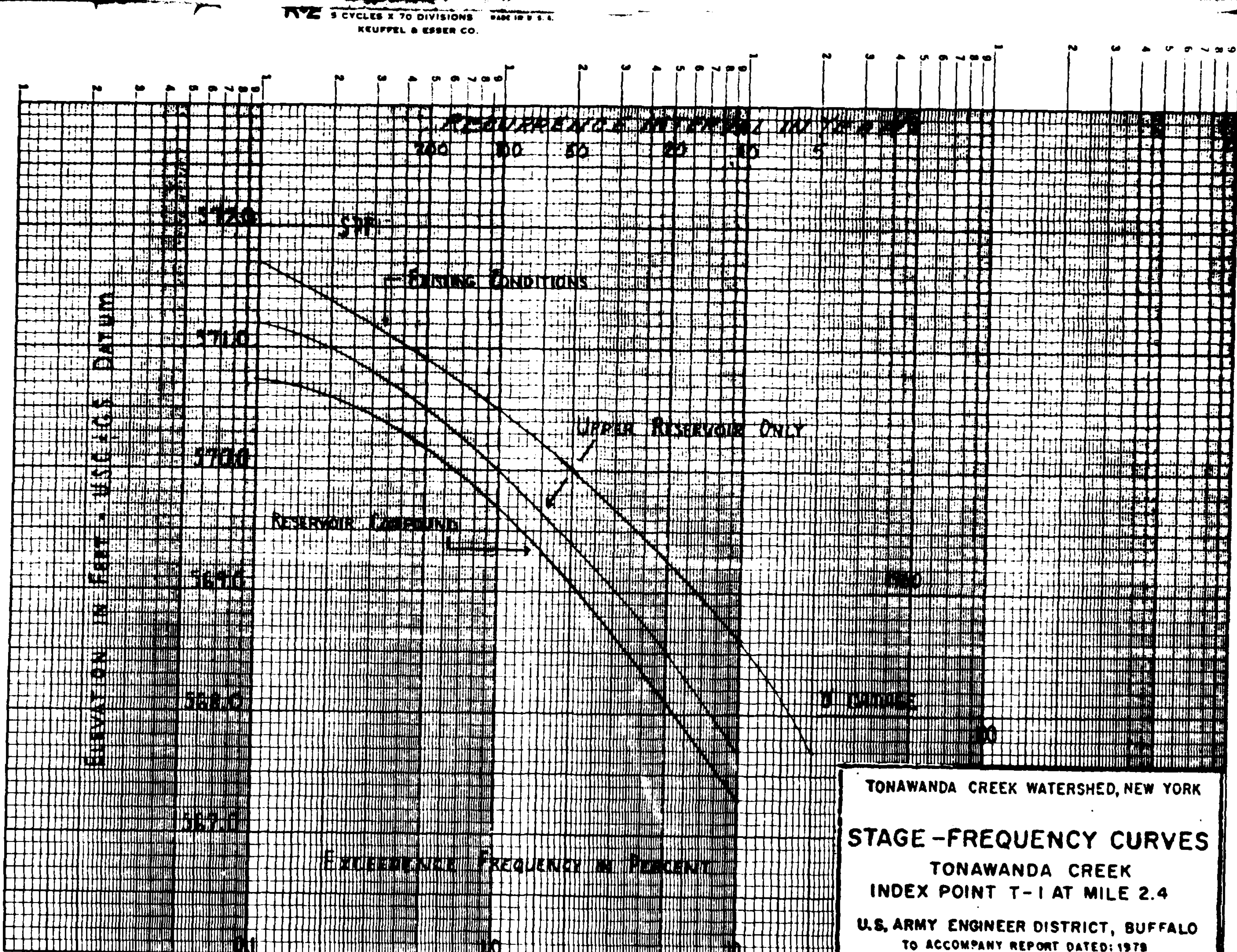
TONAWANDA CREEK

INDEX POINT T-10 AT MILE 41.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A88



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES

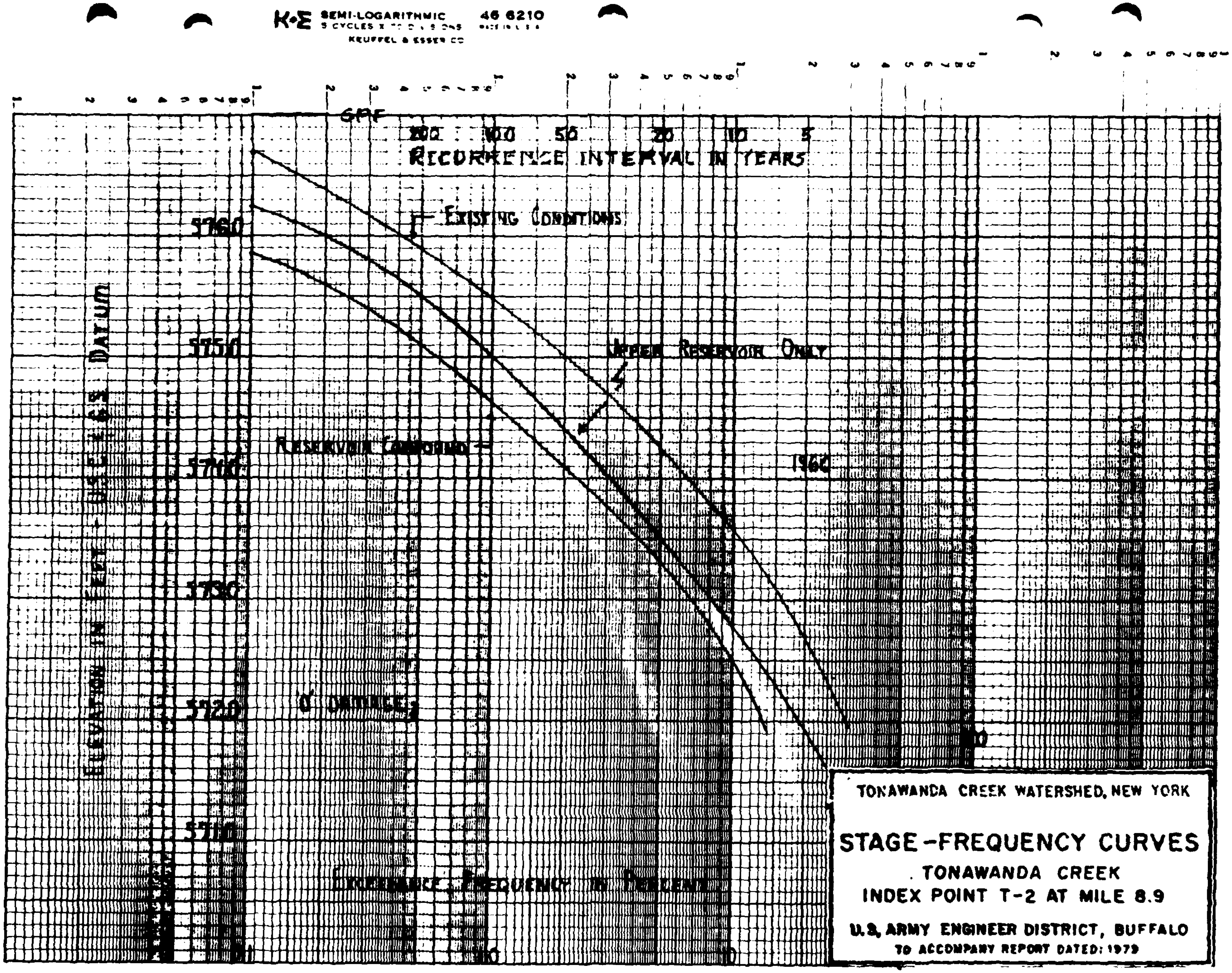
TONAWANDA CREEK

INDEX POINT T-1 AT MILE 2.4

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A19

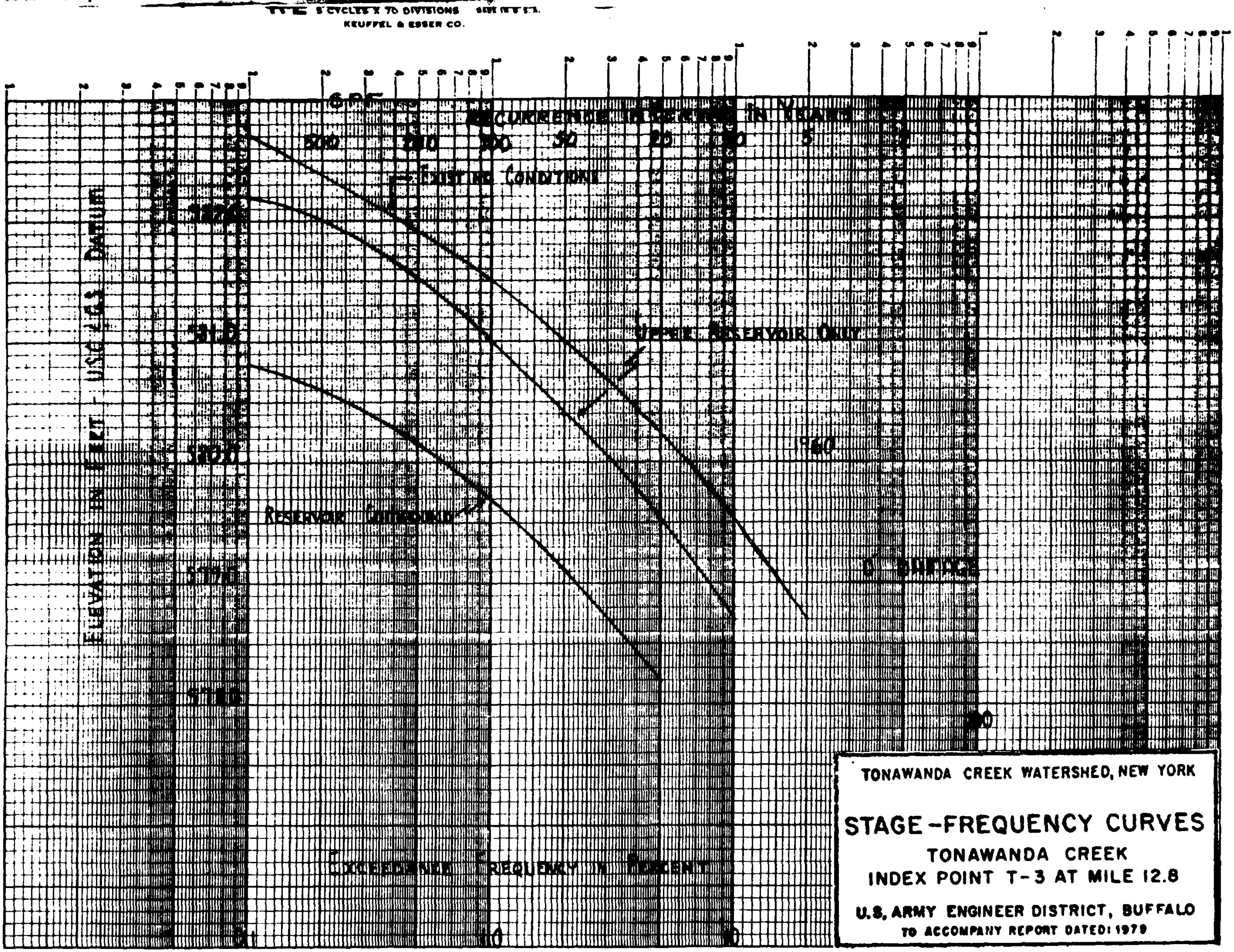


TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES

TONAWANDA CREEK
INDEX POINT T-2 AT MILE 8.9

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

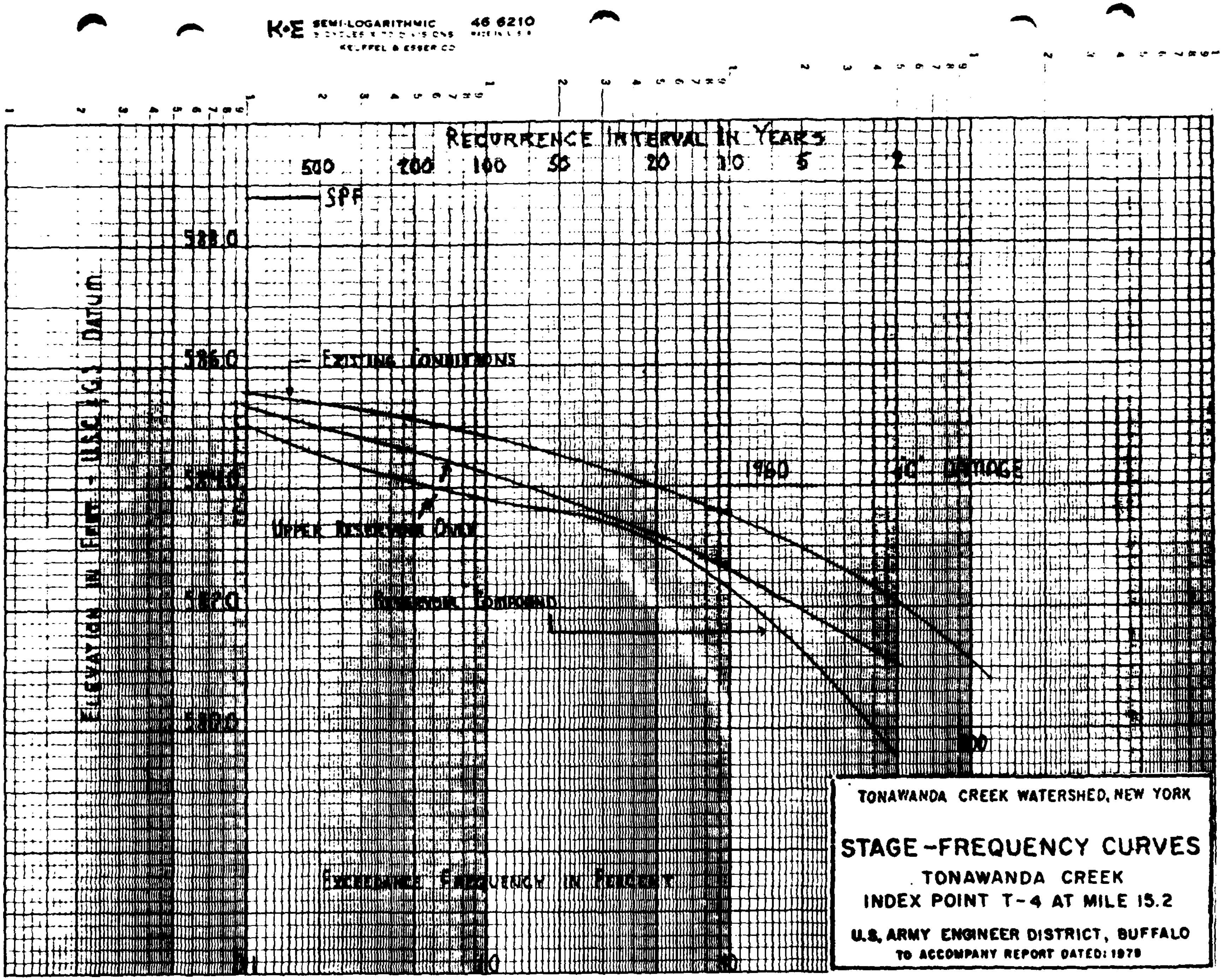
STAGE-FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT T-3 AT MILE 12.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

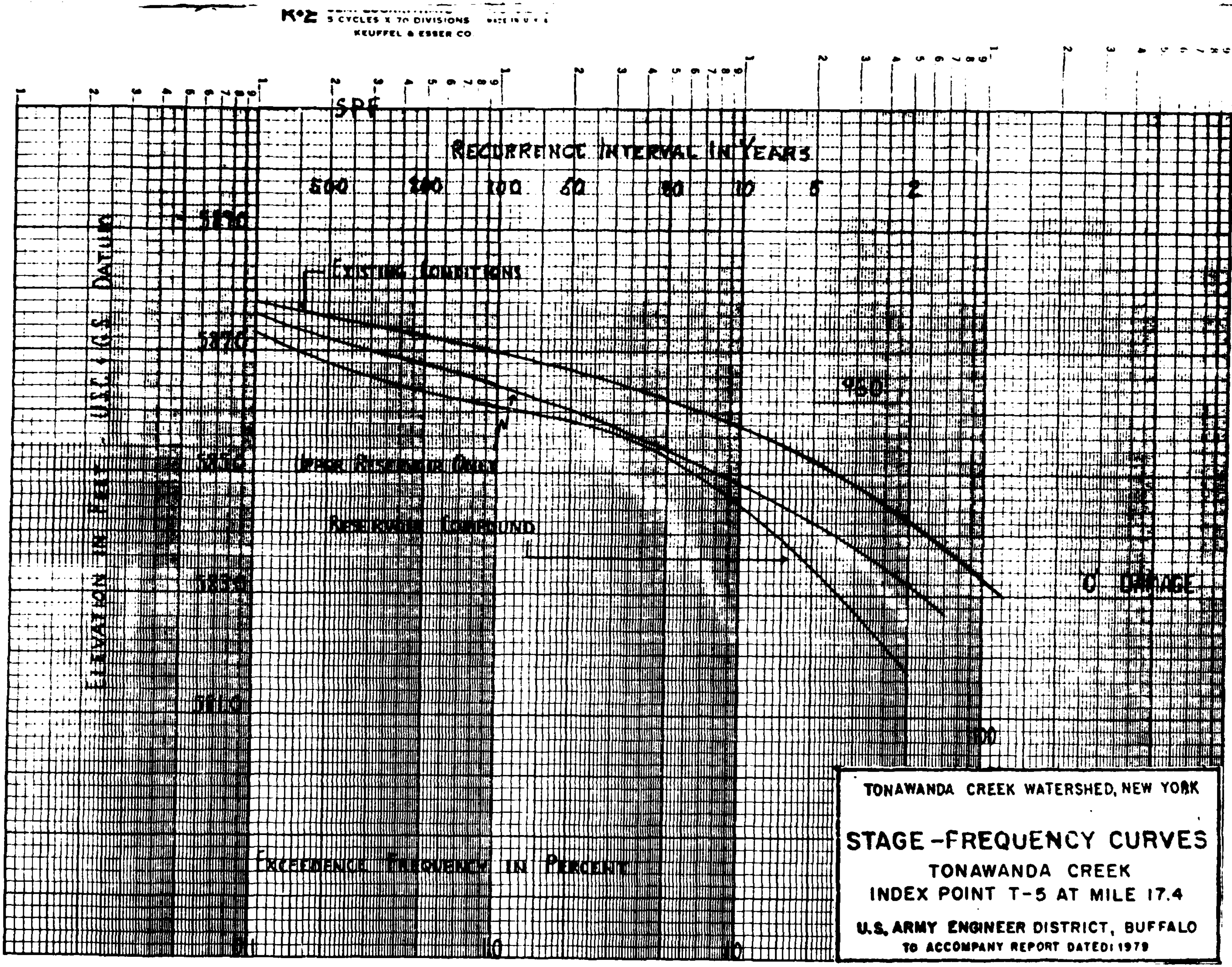
STAGE – FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT T-4 AT MILE 15.2

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

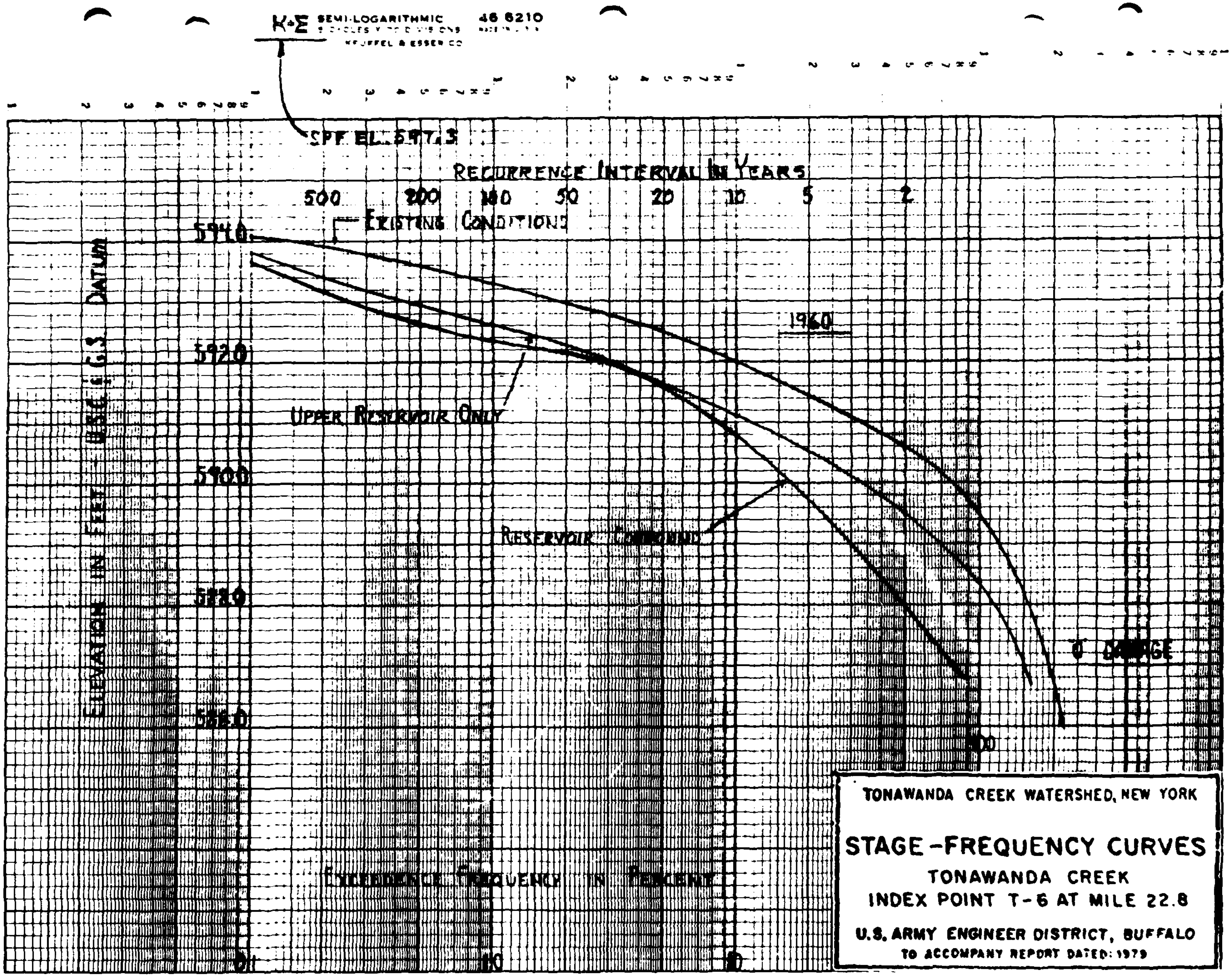
STAGE-FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT T-5 AT MILE 17.4

U.S. ARMY ENGINEER DISTRICT, BUFFALO

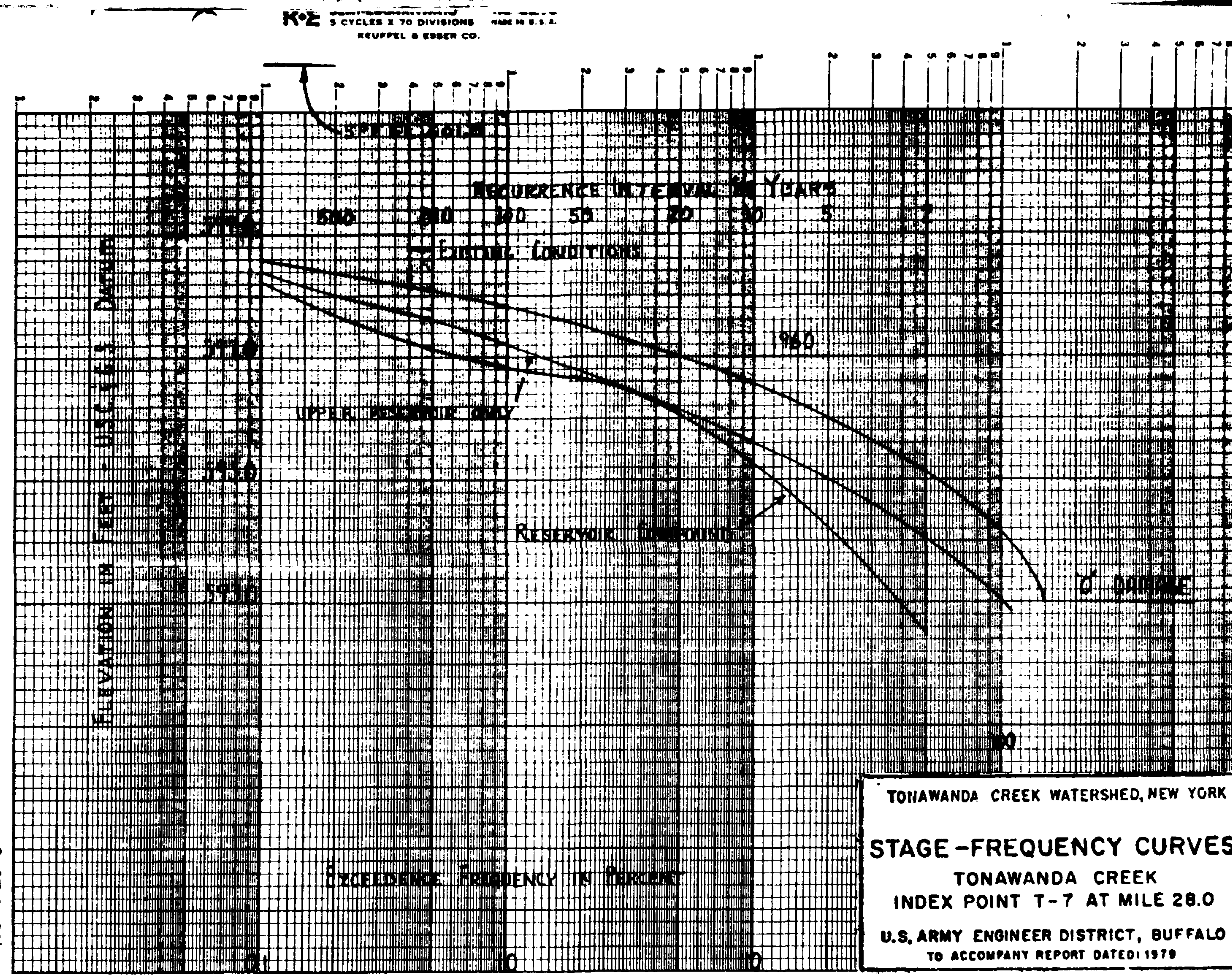
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES
TONAWANDA CREEK
INDEX POINT T-6 AT MILE 22.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

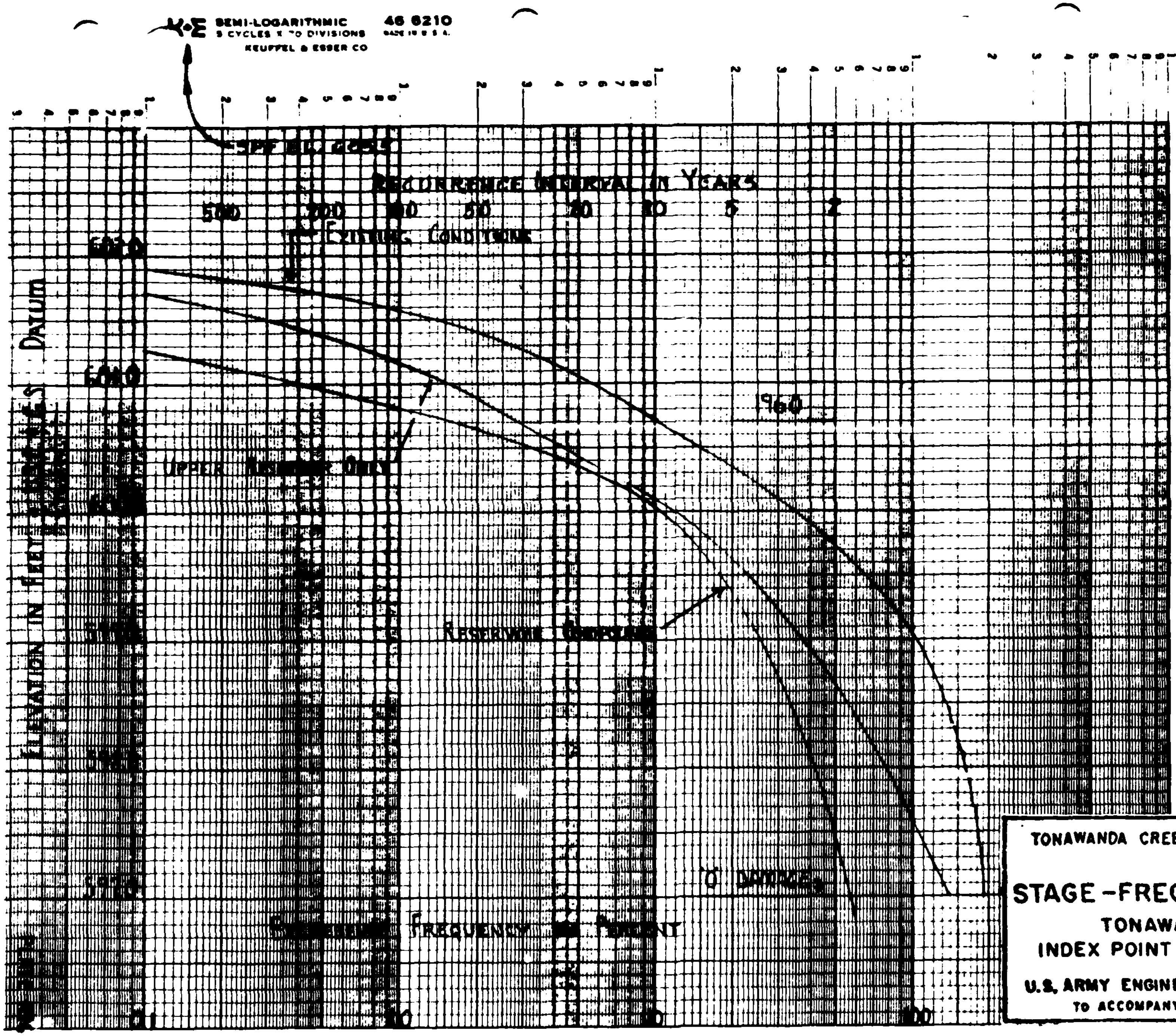


TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES

TONAWANDA CREEK
INDEX POINT T-7 AT MILE 28.0

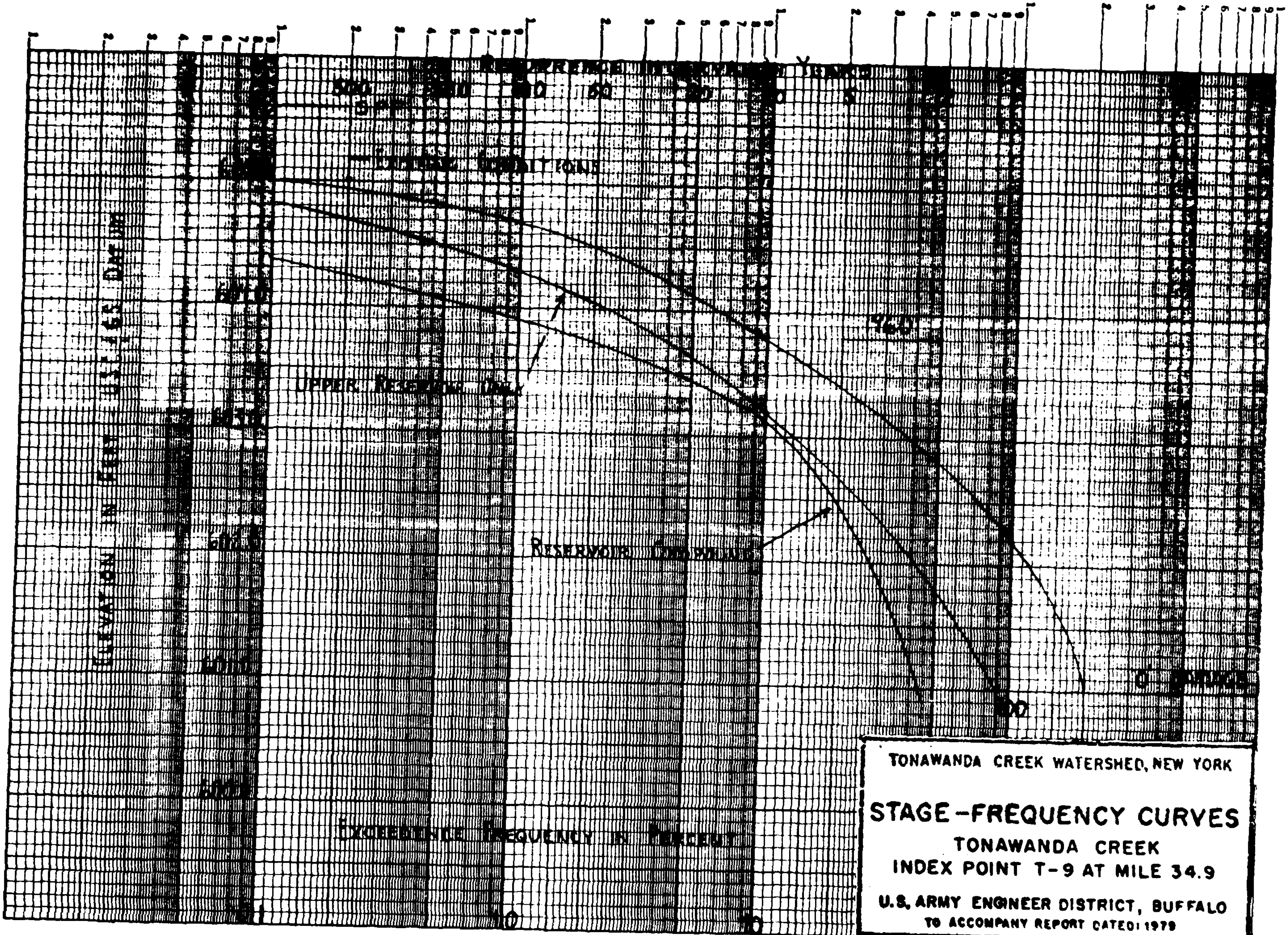
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES
TONAWANDA CREEK
INDEX POINT T-8 AT MILE 32.3

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

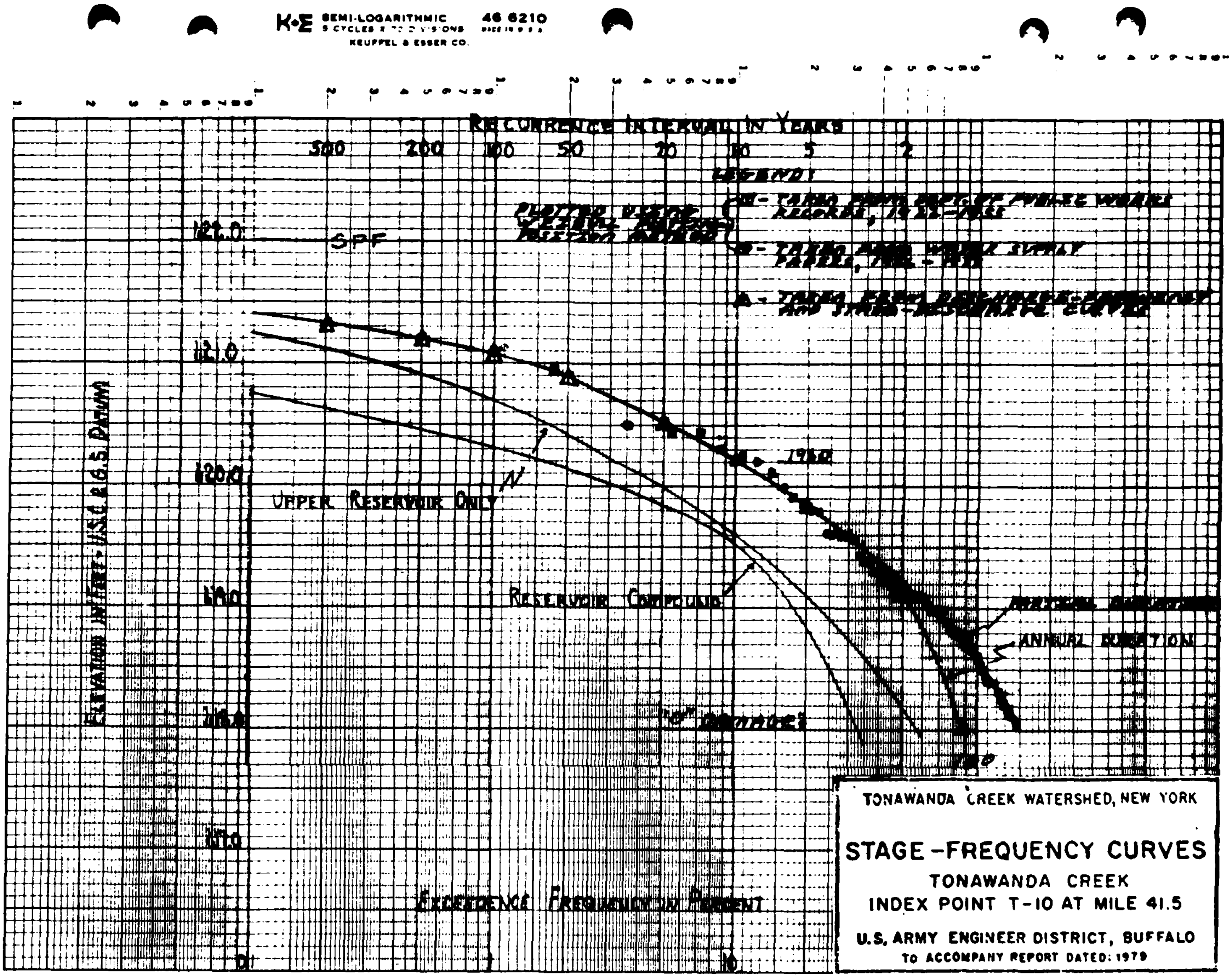
STAGE-FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT T-9 AT MILE 34.9

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - FREQUENCY CURVES

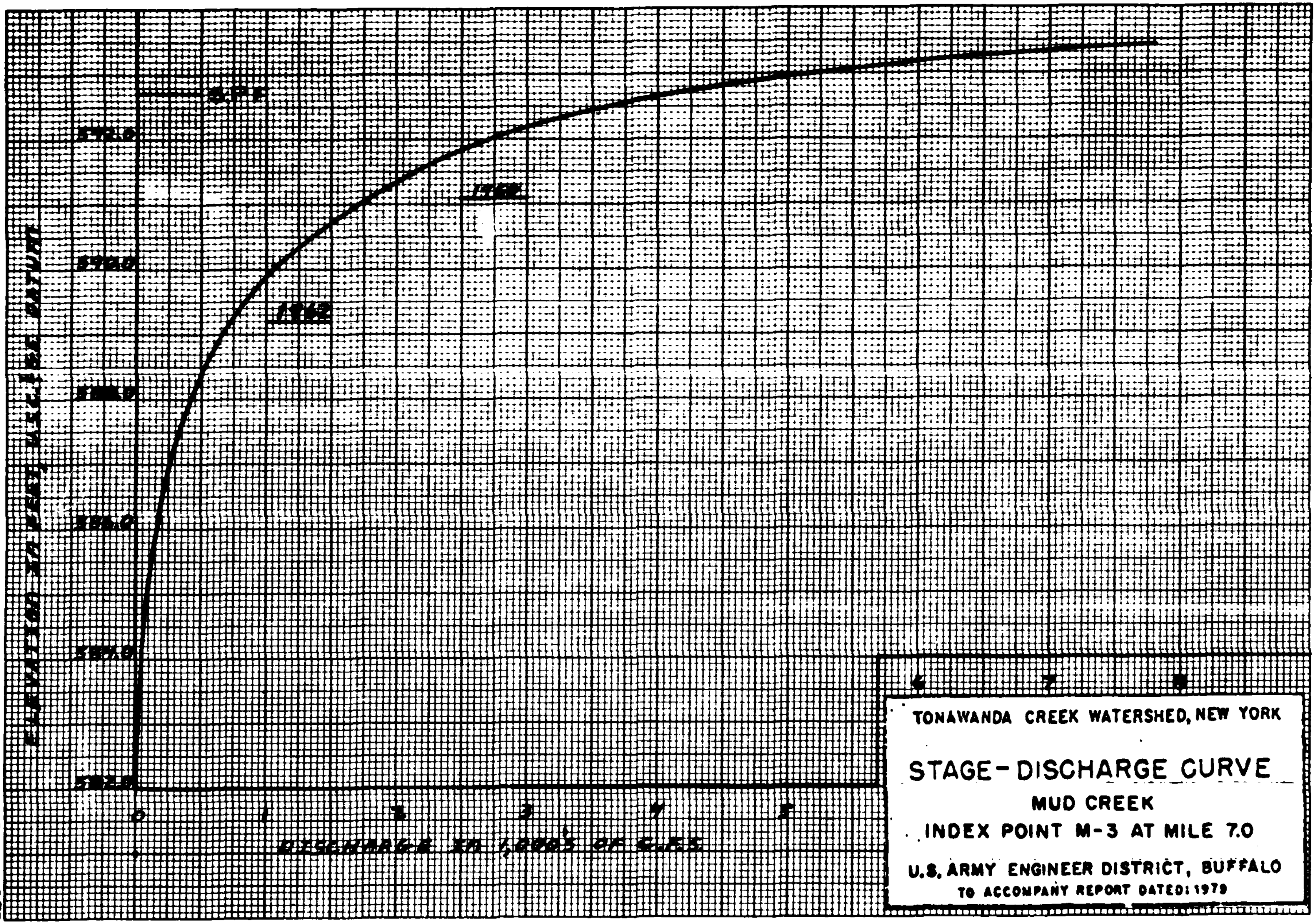
TONAWANDA CREEK

INDEX POINT T-10 AT MILE 41.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A-98



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DISCHARGE CURVE

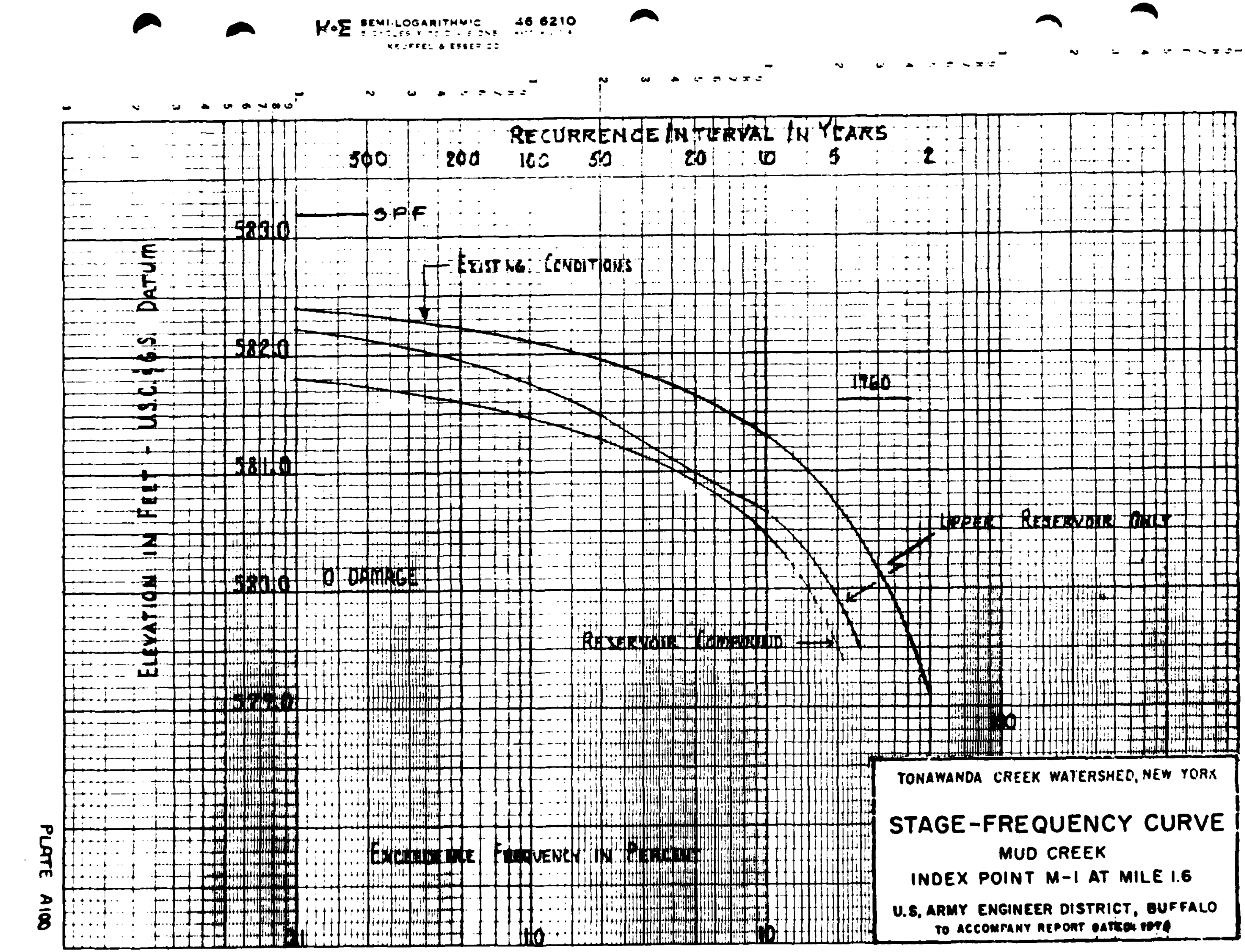
MUD CREEK

INDEX POINT M-3 AT MILE 7.0

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A98



TONAWANDA CREEK WATERSHED, NEW YORK

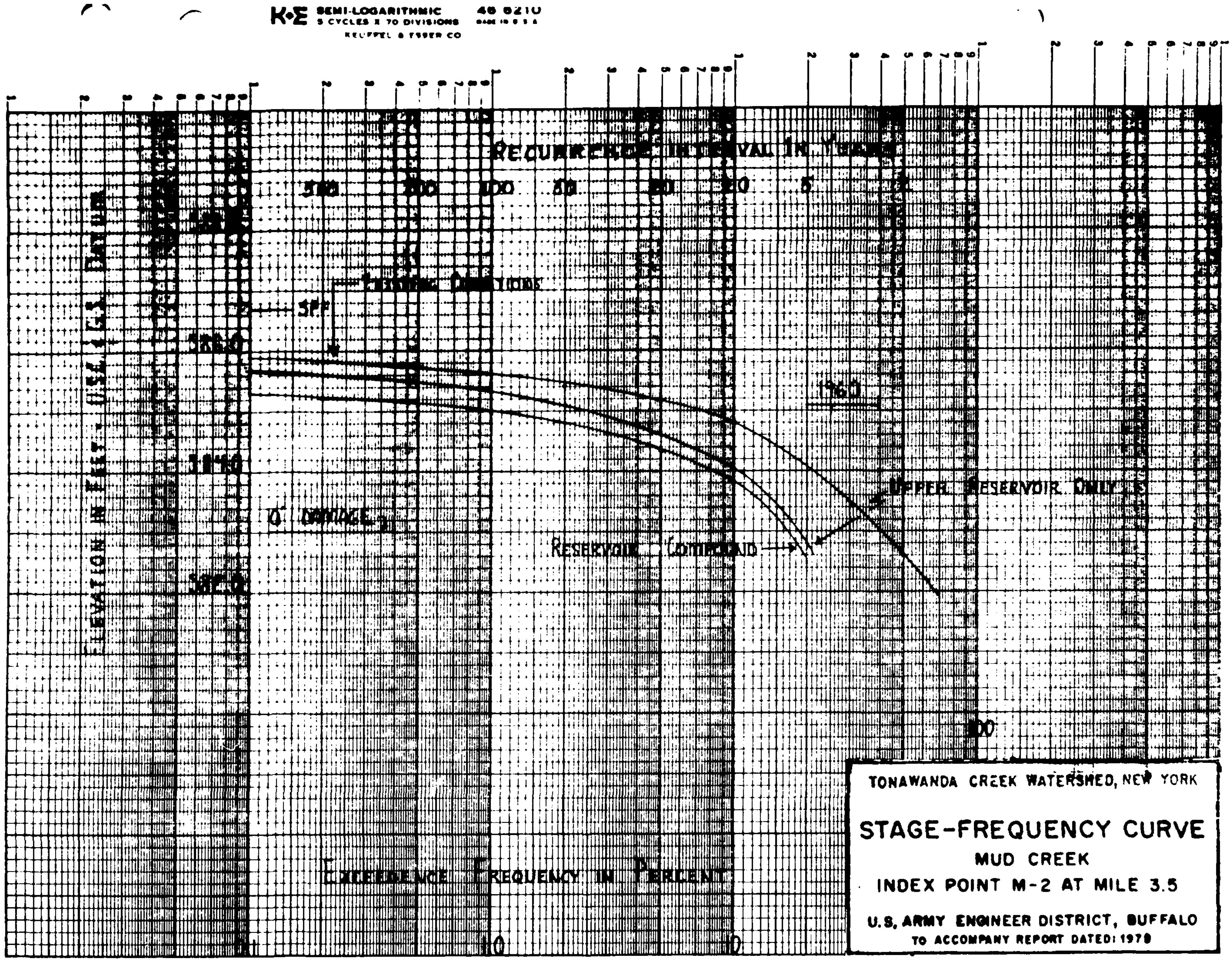
STAGE-FREQUENCY CURVE

MUD CREEK

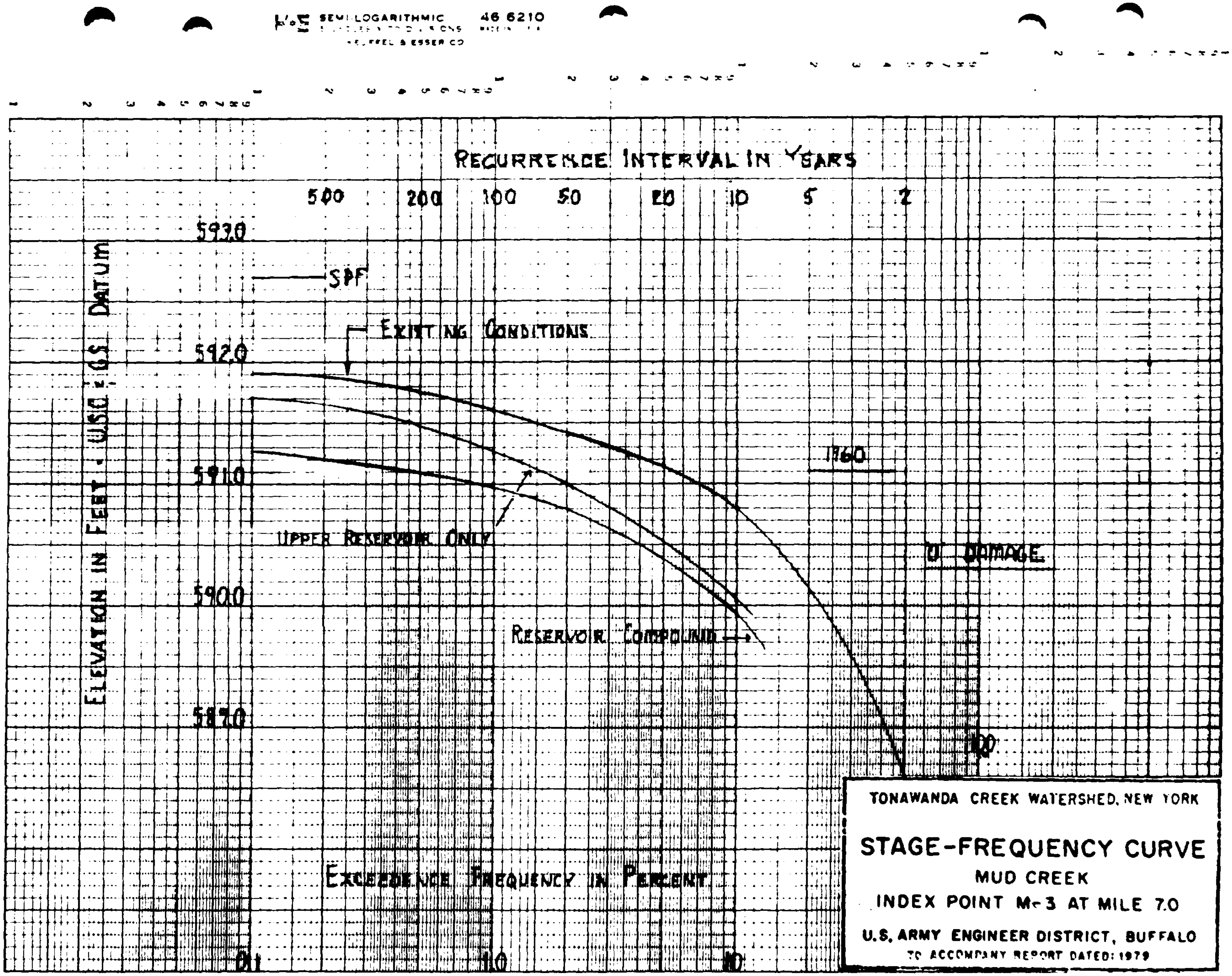
INDEX POINT M-1 AT MILE 1.6

U.S. ARMY ENGINEER DISTRICT, BUFFALO

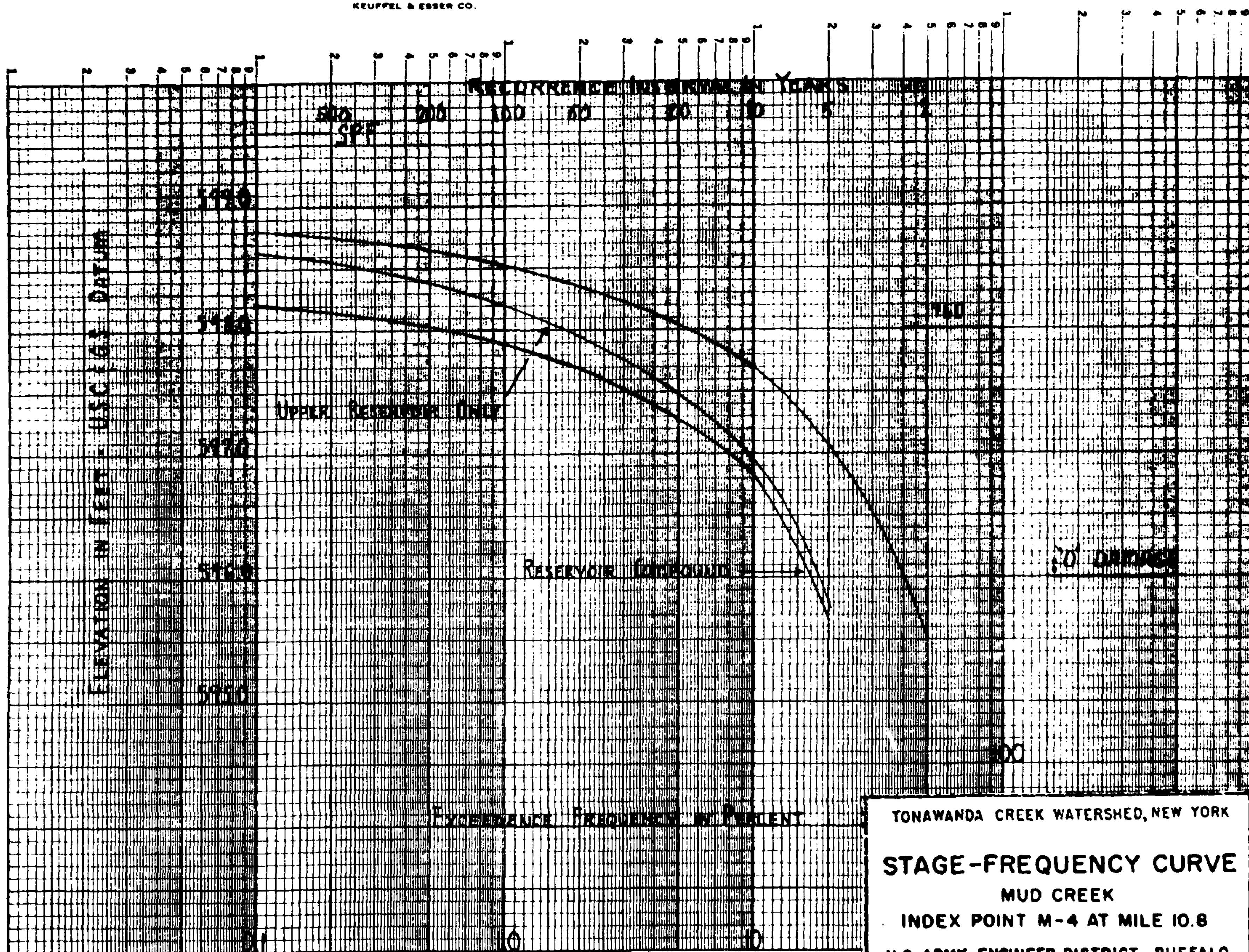
TO ACCOMPANY REPORT DATED: 1974



TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-FREQUENCY CURVE
MUD CREEK
INDEX POINT M-2 AT MILE 3.5
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
RECURRENCE INTERVAL IN YEARS
500
200
100
50
20
10
5
EXCEEDENCE FREQUENCY IN PERCENT
ELEVATION IN FEET - U.S.L.(C.S.) DATUM
SPF
EXISTING CONDITIONS
O DAMAGE
UPPER RESERVOIR ONLY
RESERVOIR COMBINED
1960
K•E SEMI-LOGARITHMIC 46 5210
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.



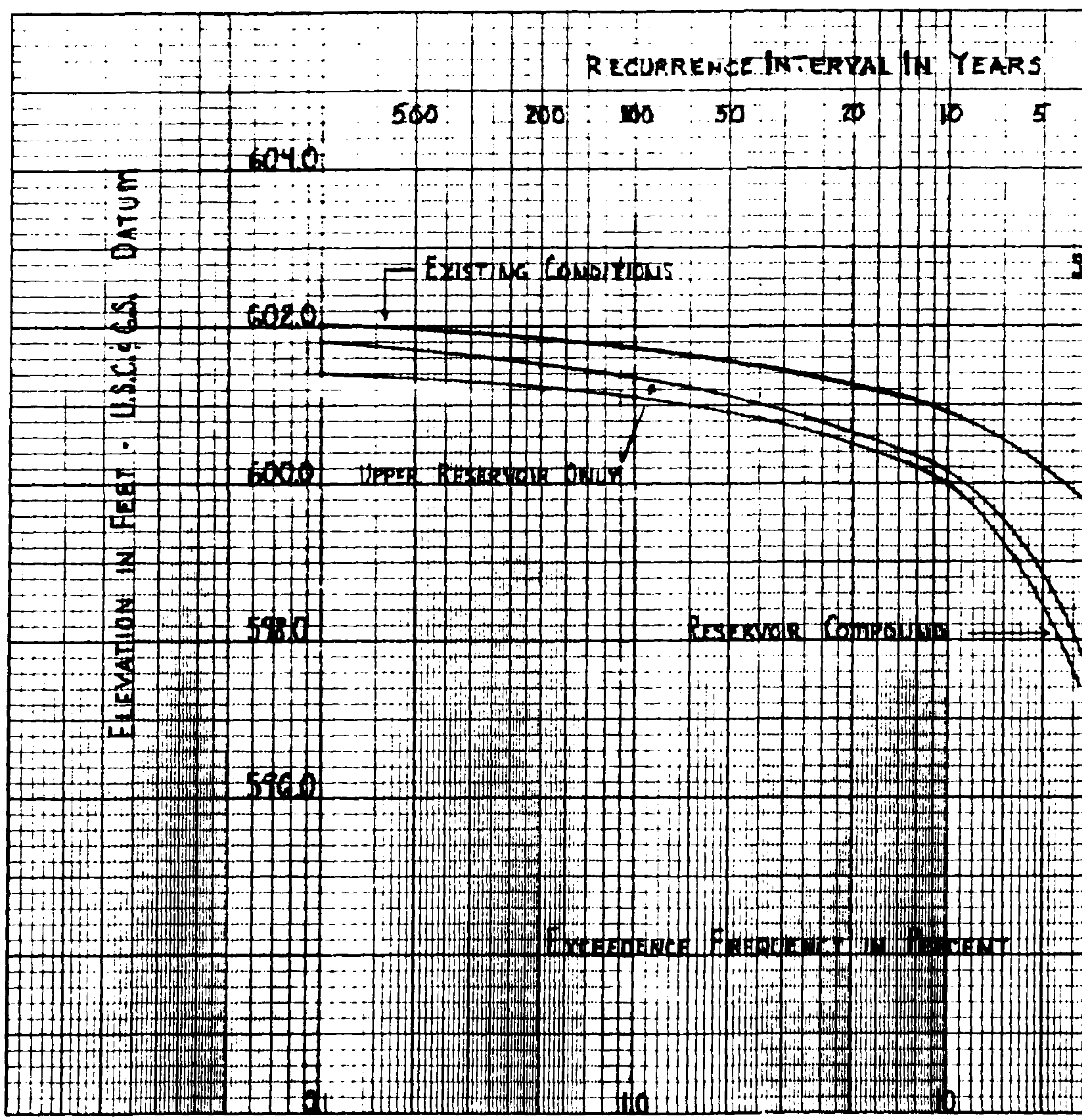
K&E SEMI-LOGARITHMIC 46 6210
KEUFFEL & ESSER CO.
RECURRENCE INTERVAL IN YEARS
500
200
100
50
20
10
5
2
593.0
592.0
591.0
590.0
SPF
EXISTING CONDITIONS
UPPER RESERVOIR ONLY
RESERVOIR COMPOUND
1960
ELEVATION IN FEET - USC & GS DATUM
EXCEEDENCE FREQUENCY IN PERCENT
0.1
1.0
10
100
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-FREQUENCY CURVE
MUD CREEK
INDEX POINT M-3 AT MILE 7.0
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVE
MUD CREEK
INDEX POINT M-4 AT MILE 10.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVE

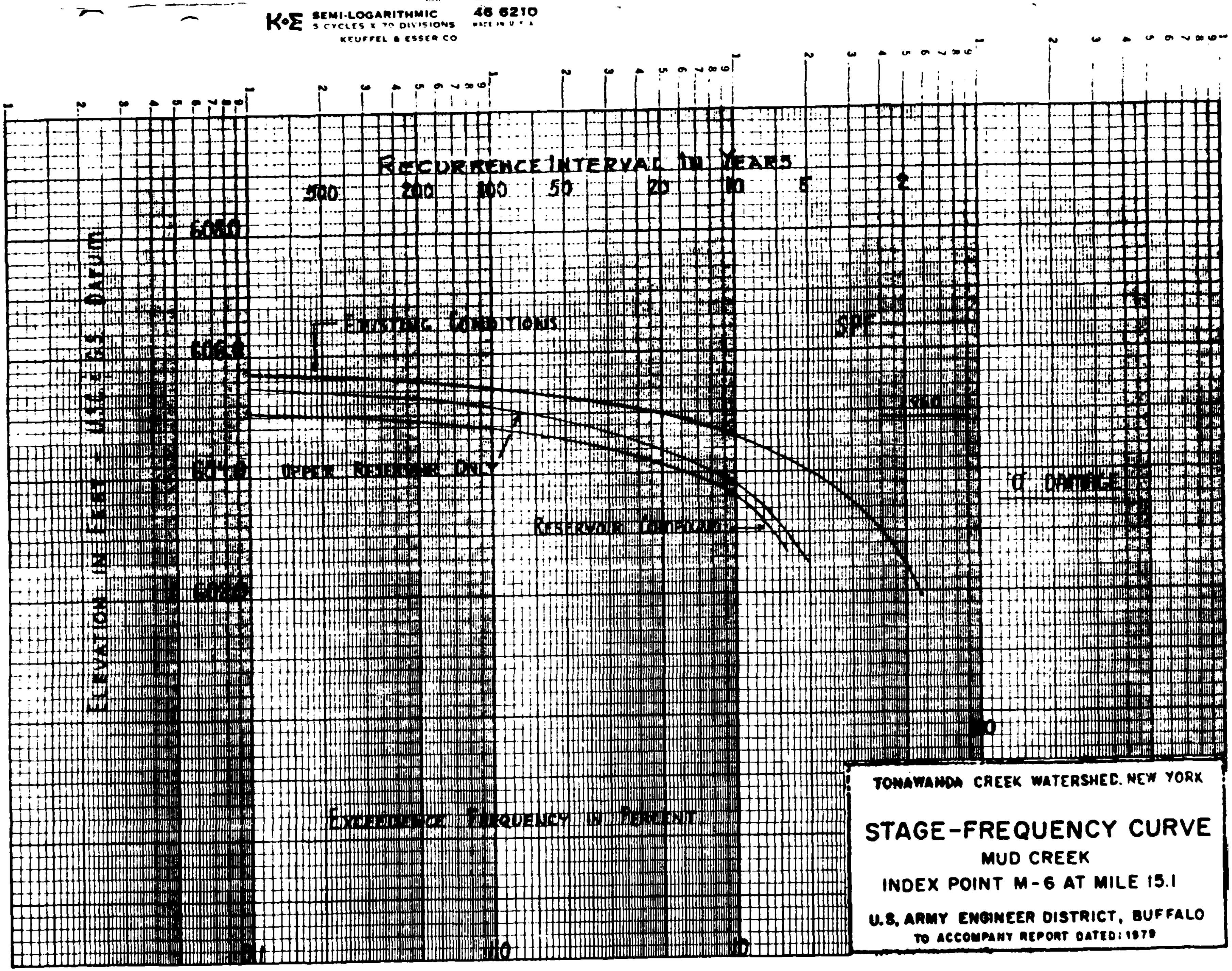
MUD CREEK

INDEX POINT M-5 AT MILE 12.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A104



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVE

MUD CREEK

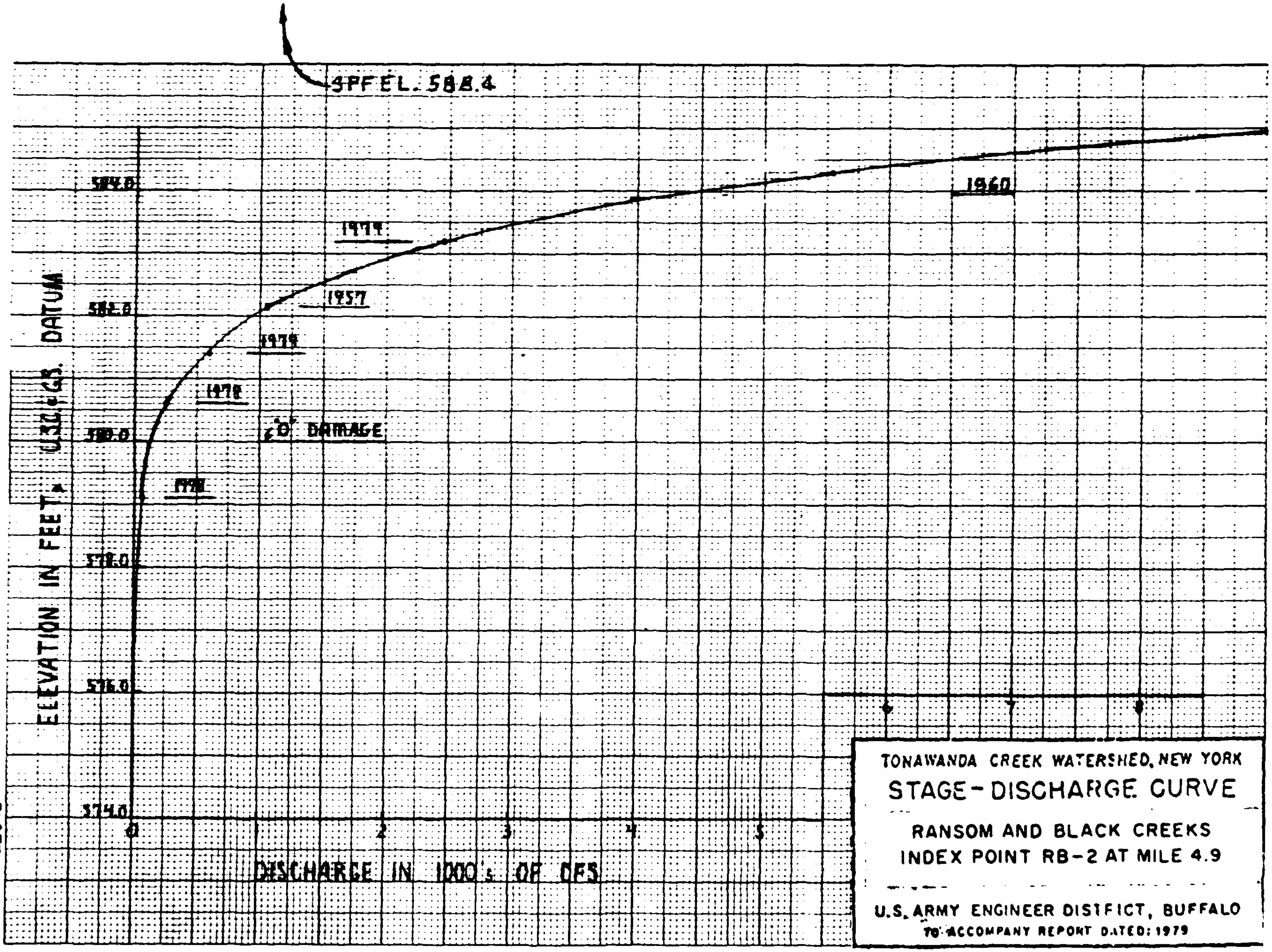
INDEX POINT M-6 AT MILE 15.1

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

K+E 10 X 10 TO ½ INCH

46 1320



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DISCHARGE CURVE

RANSOM AND BLACK CREEKS
INDEX POINT RB-2 AT MILE 4.9

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

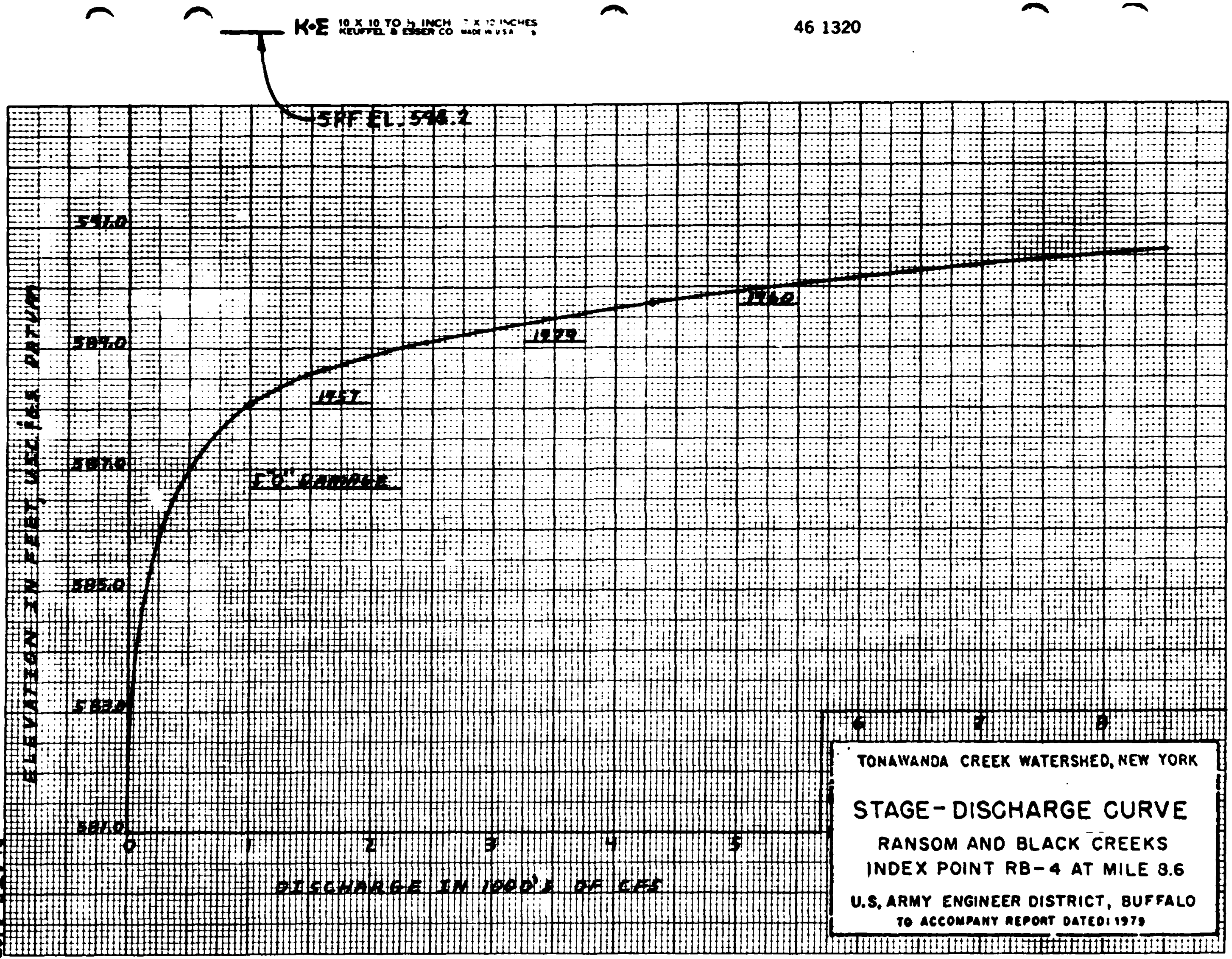
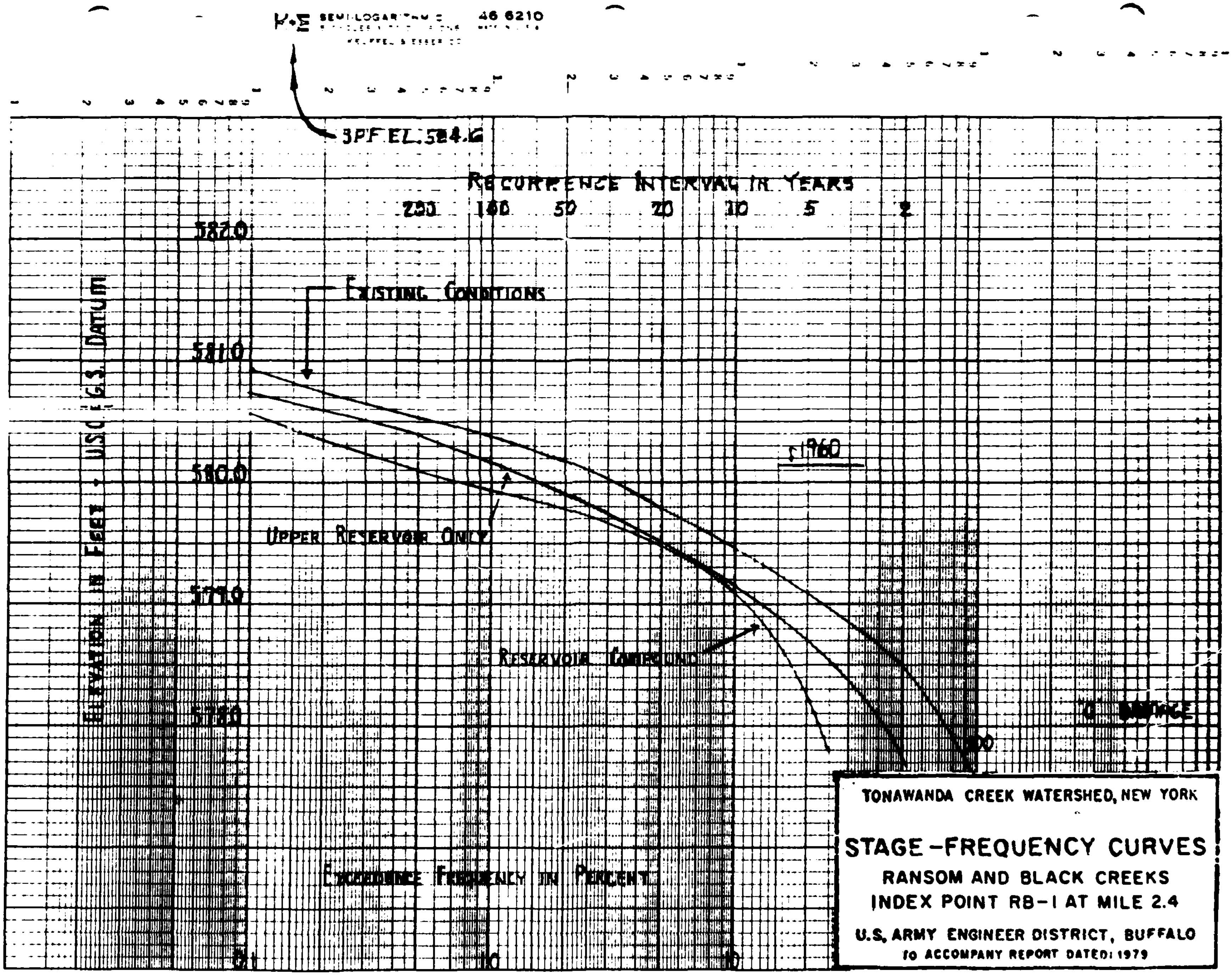

K•E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1320
SPF EL. 598.2
591.0
589.0
587.0
585.0
583.0
581.0
1957
1979
1960
1'0" DAMAGE
0
1
2
3
4
5
6
7
8
ELEVATION IN FEET, USC.[illegible] DATUM
DISCHARGE IN 1000'S OF CFS
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE - DISCHARGE CURVE
RANSOM AND BLACK CREEKS
INDEX POINT RB-4 AT MILE 8.6
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A107



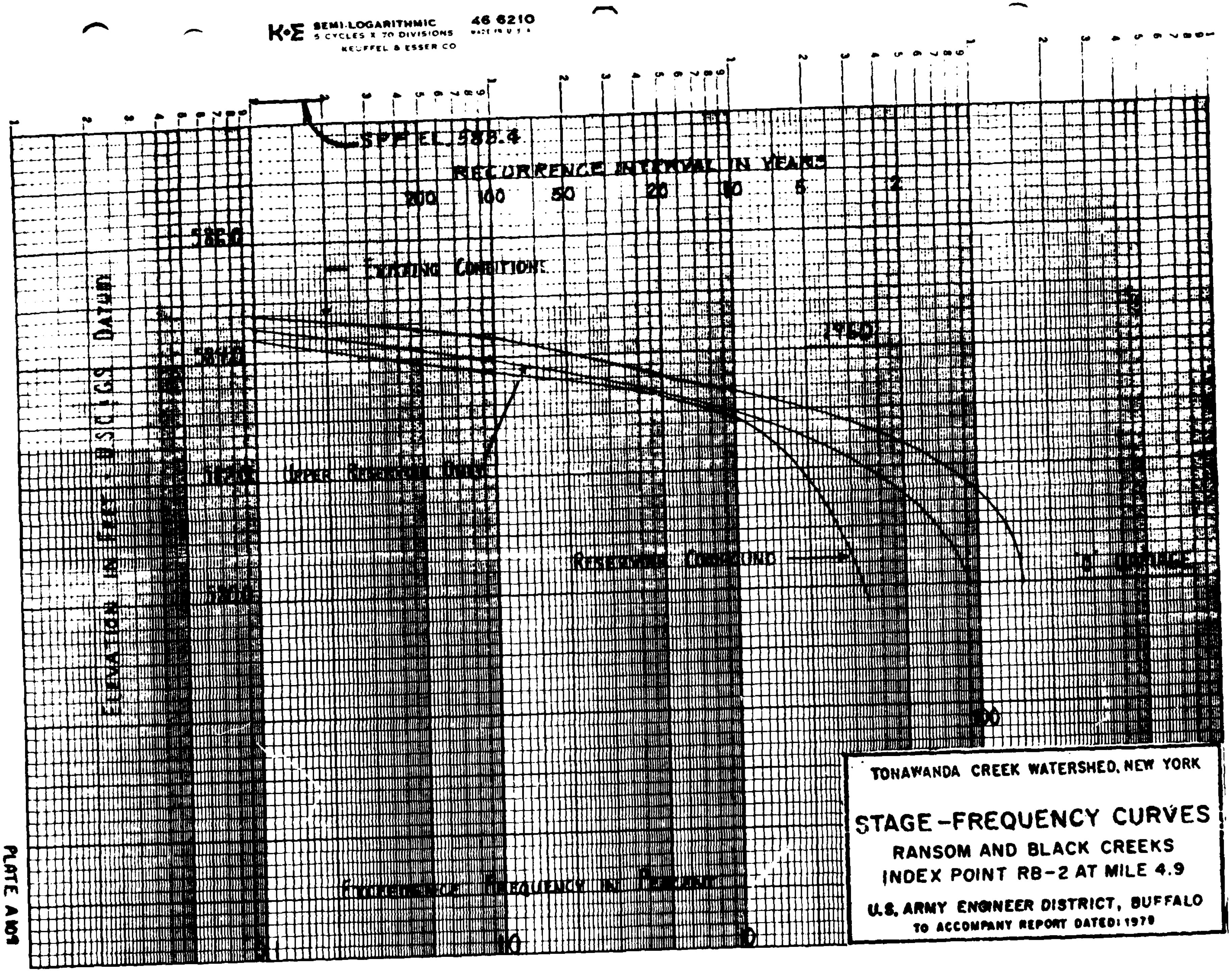
TONAWANDA CREEK WATERSHED, NEW YORK

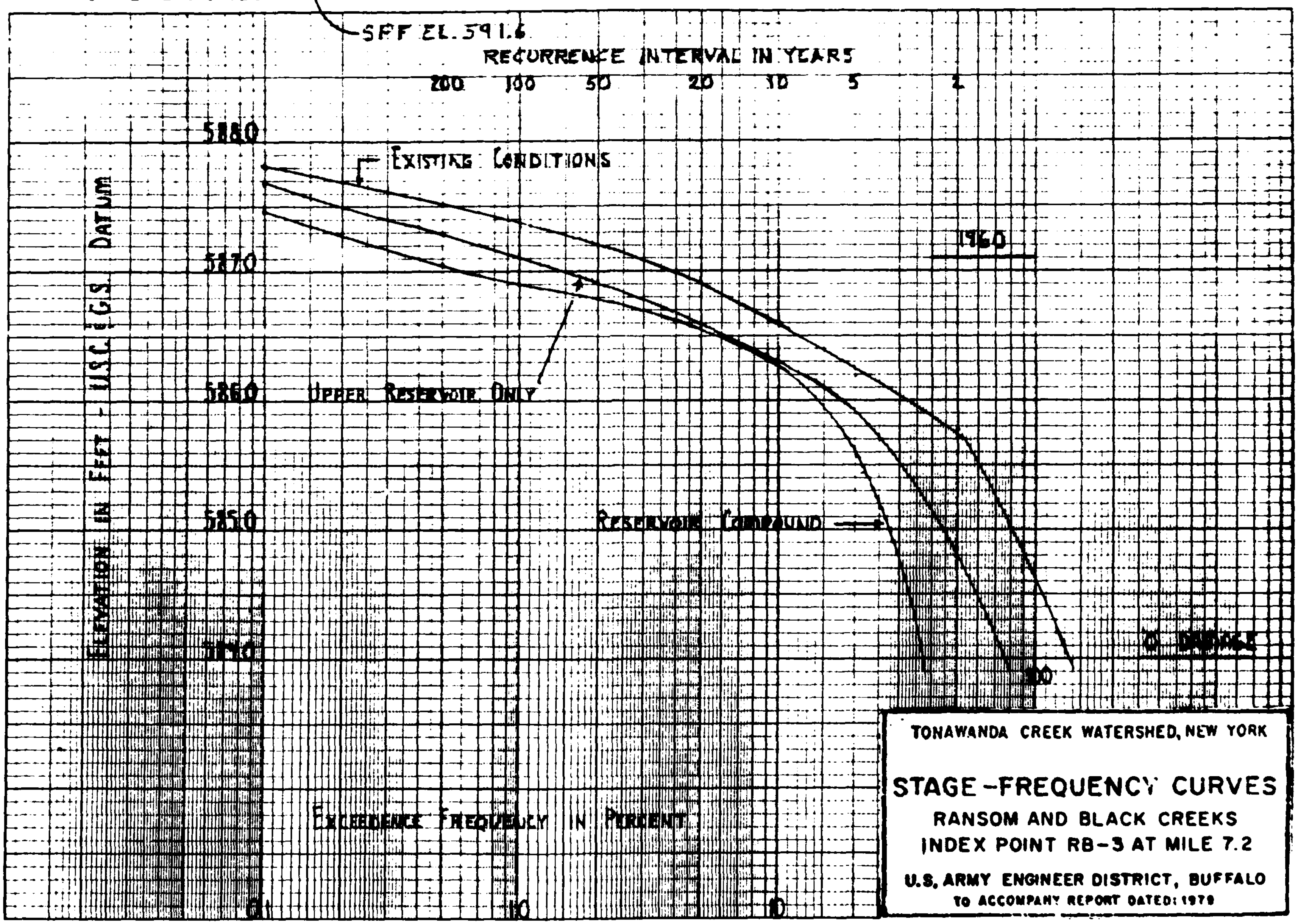
STAGE-FREQUENCY CURVES

RANSOM AND BLACK CREEKS
INDEX POINT RB-1 AT MILE 2.4

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A108


K&E SEMI-LOGARITHMIC 46 6210
5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO
SPF EL 588.4
RECURRENCE INTERVAL IN YEARS
200 100 50 20 10 5 2
EXISTING CONDITIONS
UPPER RESERVOIR ONLY
RESERVOIRS COMBINED
ELEVATION IN FEET U.S.C.&G.S. DATUM
EXCEEDENCE FREQUENCY IN PERCENT
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-FREQUENCY CURVES
RANSOM AND BLACK CREEKS
INDEX POINT RB-2 AT MILE 4.9
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES

RANSOM AND BLACK CREEKS
INDEX POINT RB-3 AT MILE 7.2

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A110

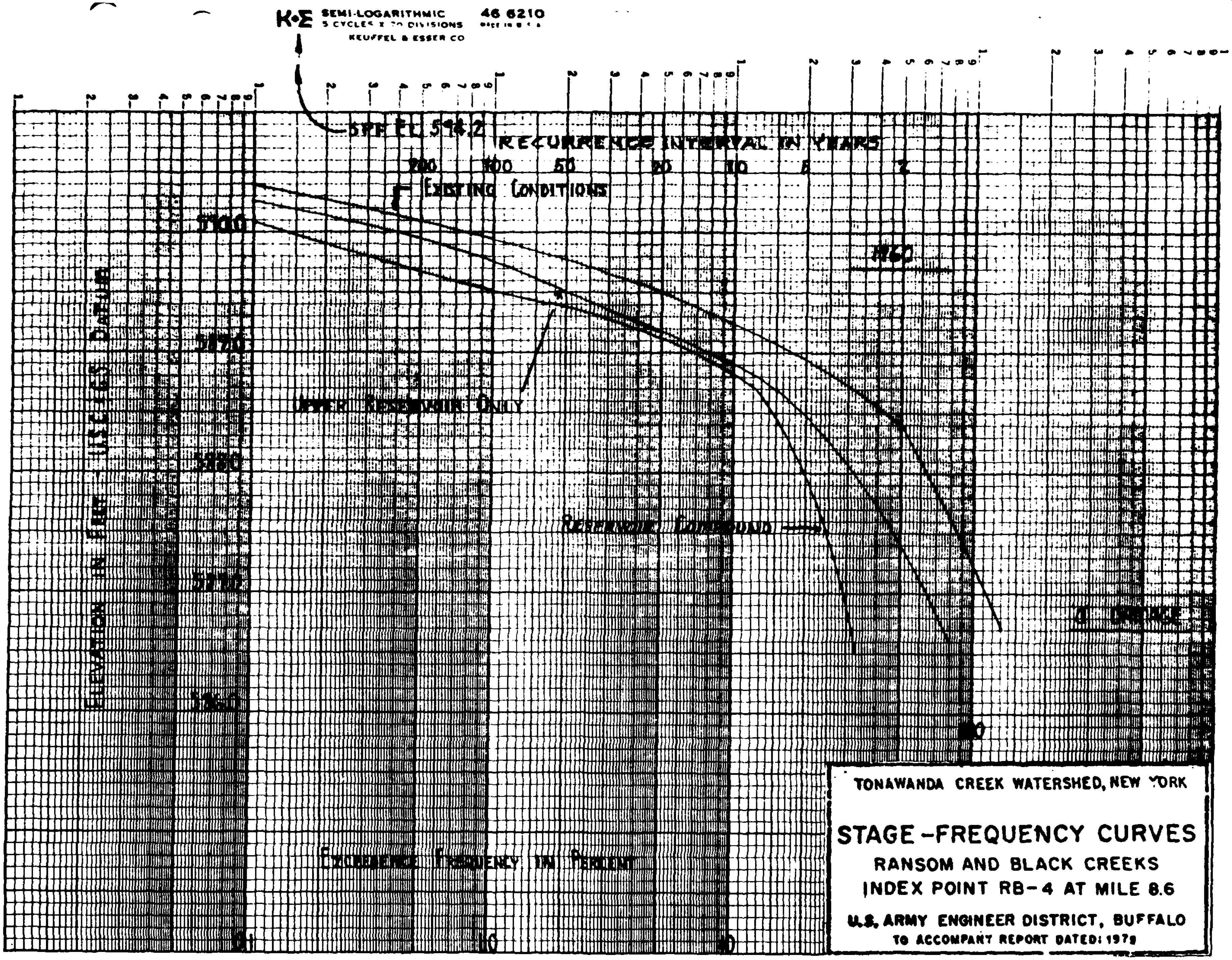
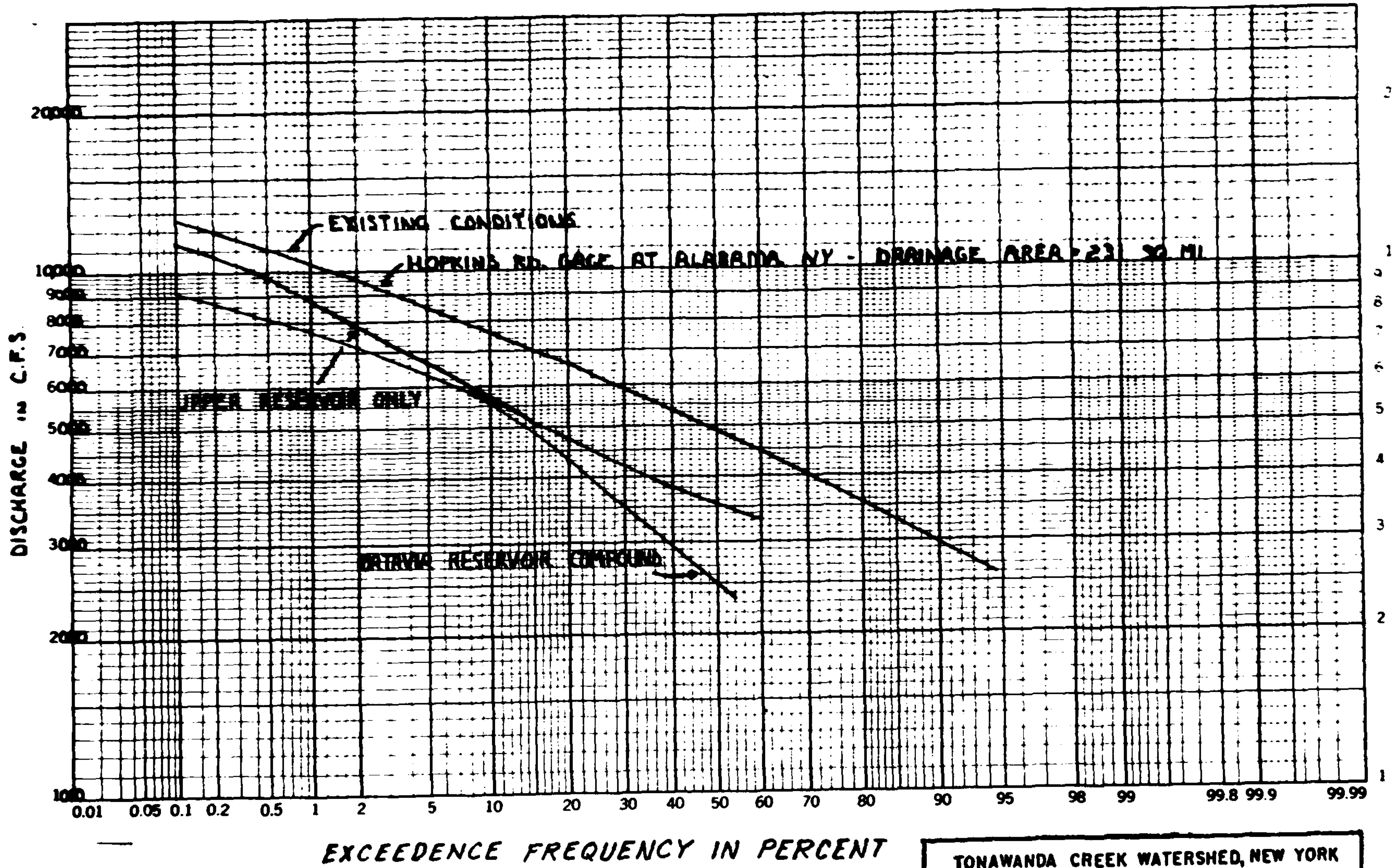

K•E SEMI-LOGARITHMIC 46 6210
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO
SPF EL 5912
RECURRENCE INTERVAL IN YEARS
200 100 50 20 10 5 2
EXISTING CONDITIONS
UPPER RESERVOIR ONLY
RESERVOIR COMBINED
ELEVATION IN FEET - U.S.C.&G.S. DATUM
EXCEEDENCE FREQUENCY IN PERCENT
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-FREQUENCY CURVES
RANSOM AND BLACK CREEKS
INDEX POINT RB-4 AT MILE 8.6
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE AM1



TONAWANDA CREEK WATERSHED, NEW YORK

PEAK DISCHARGE-
FREQUENCY CURVES
AT HOPKINS ROAD GAGE
TONAWANDA CREEK

INDEX POINT T-10 AT MILE 41.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A11R

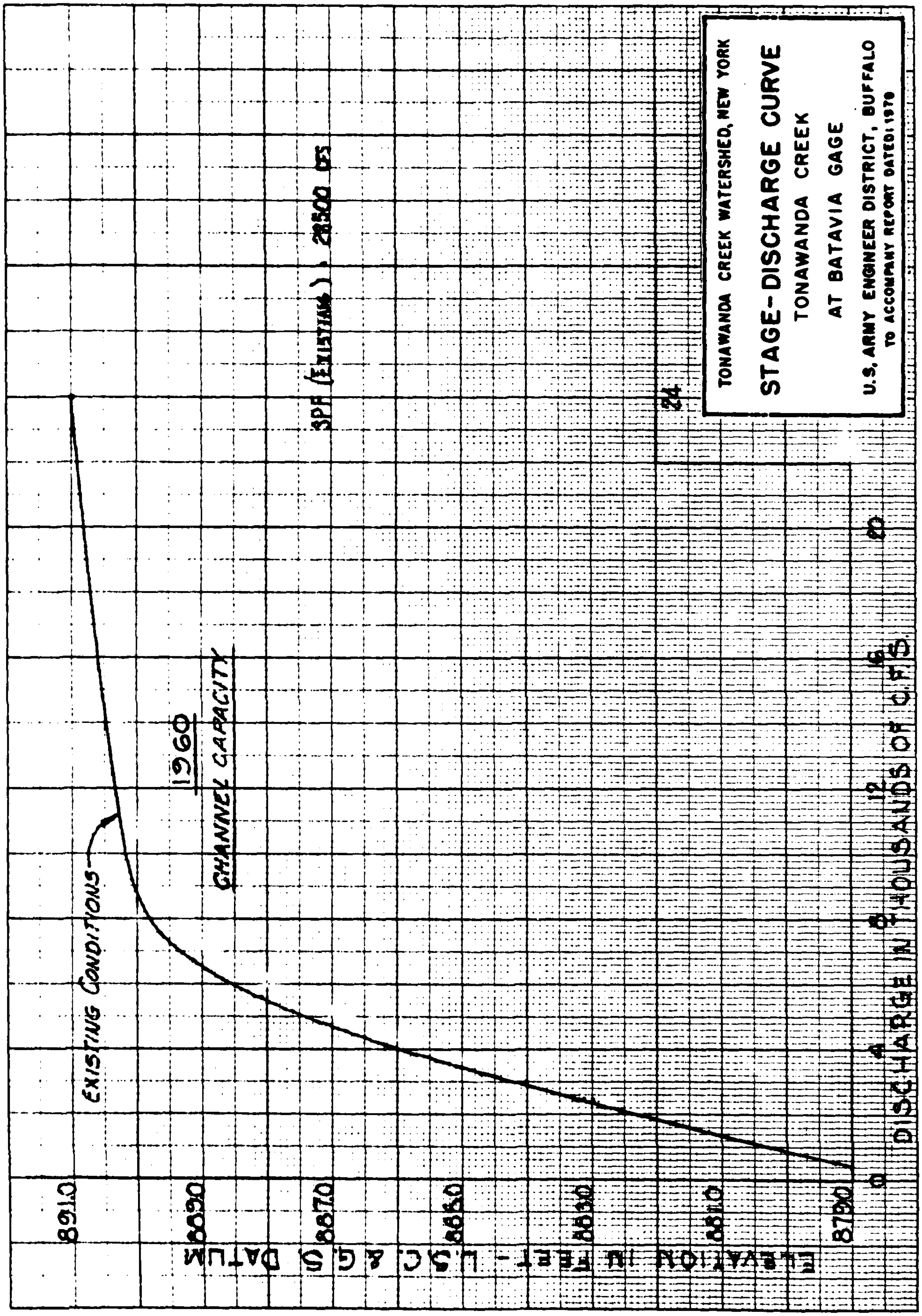

TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-DISCHARGE CURVE
TONAWANDA CREEK
AT BATAVIA GAGE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1970
SPF (EXISTING) 28500 CFS
1960
CHANNEL CAPACITY
EXISTING CONDITIONS
0
4
8
12
16
20
24
DISCHARGE IN THOUSANDS OF C.F.S.
8790
8810
8830
8850
8870
8890
891.0
ELEVATION IN FEET - U.S.C. & G.S. DATUM

PLATE A113

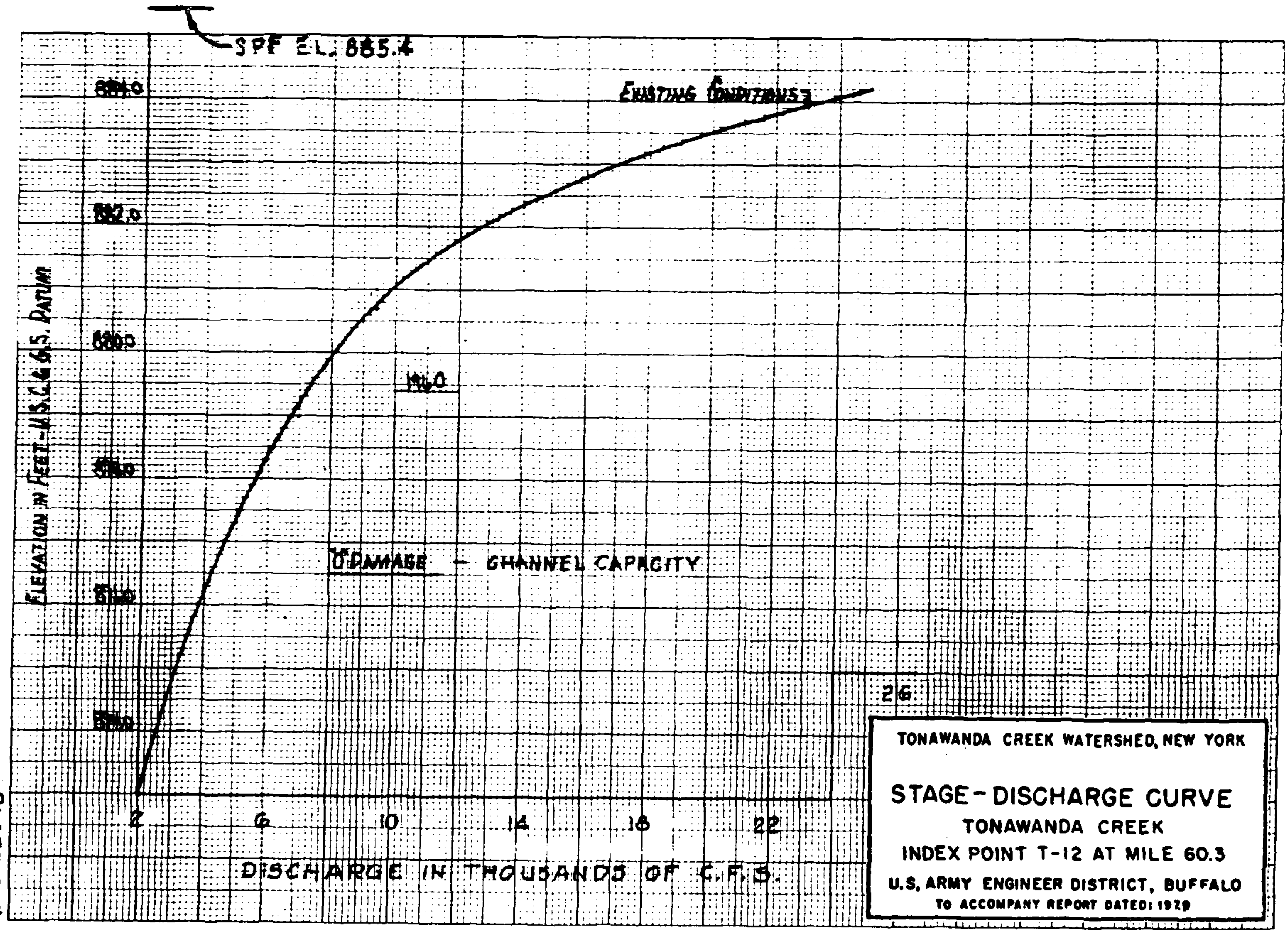
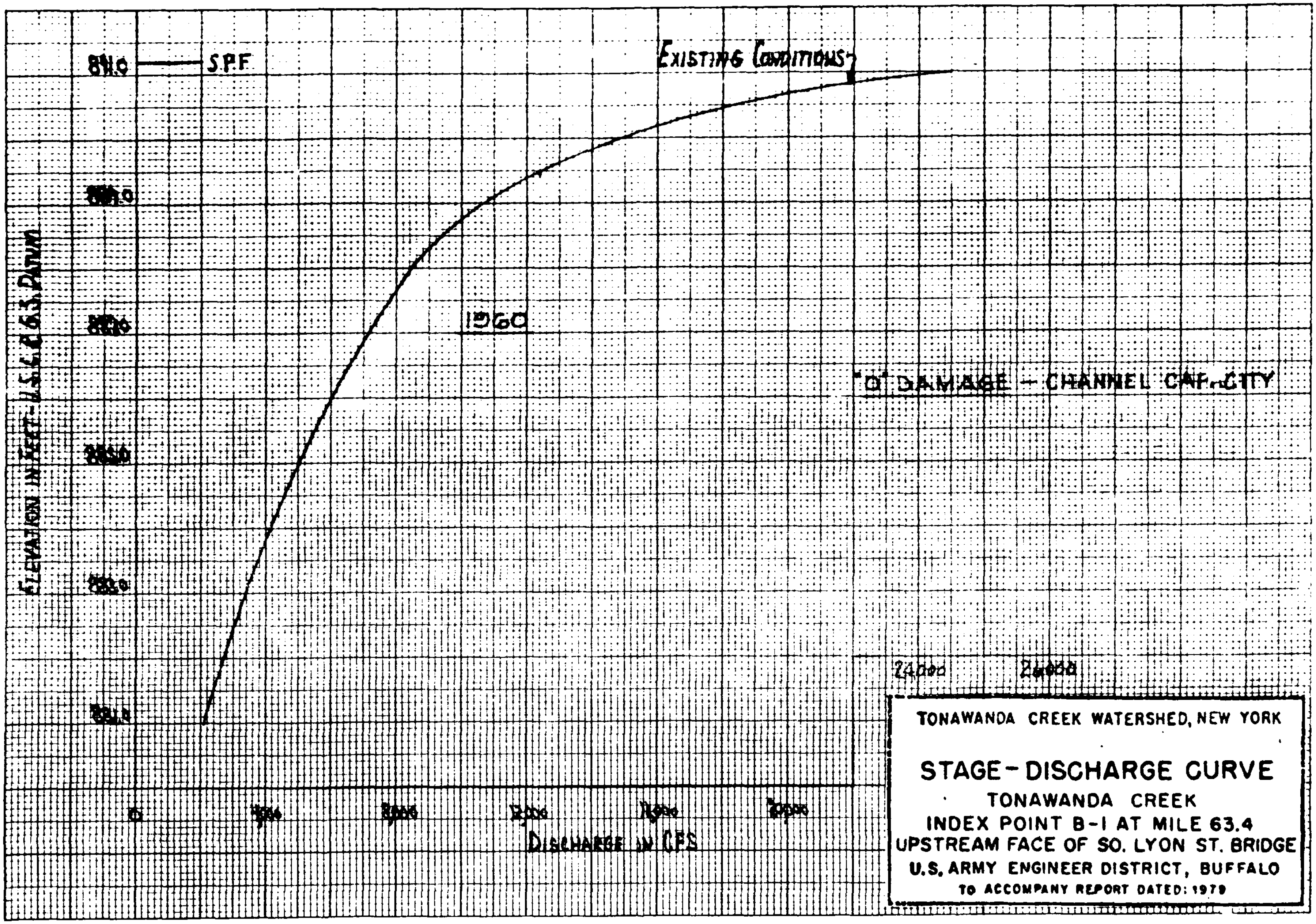

SPF EL. 885.4
EXISTING CONDITIONS
14.0
DAMAGE - CHANNEL CAPACITY
ELEVATION IN FEET-U.S.C.& G.S. DATUM
2
6
10
14
18
22
26
DISCHARGE IN THOUSANDS OF C.F.S.
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-DISCHARGE CURVE
TONAWANDA CREEK
INDEX POINT T-12 AT MILE 60.3
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A.114



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DISCHARGE CURVE

TONAWANDA CREEK

INDEX POINT B-I AT MILE 63.4

UPSTREAM FACE OF SO. LYON ST. BRIDGE

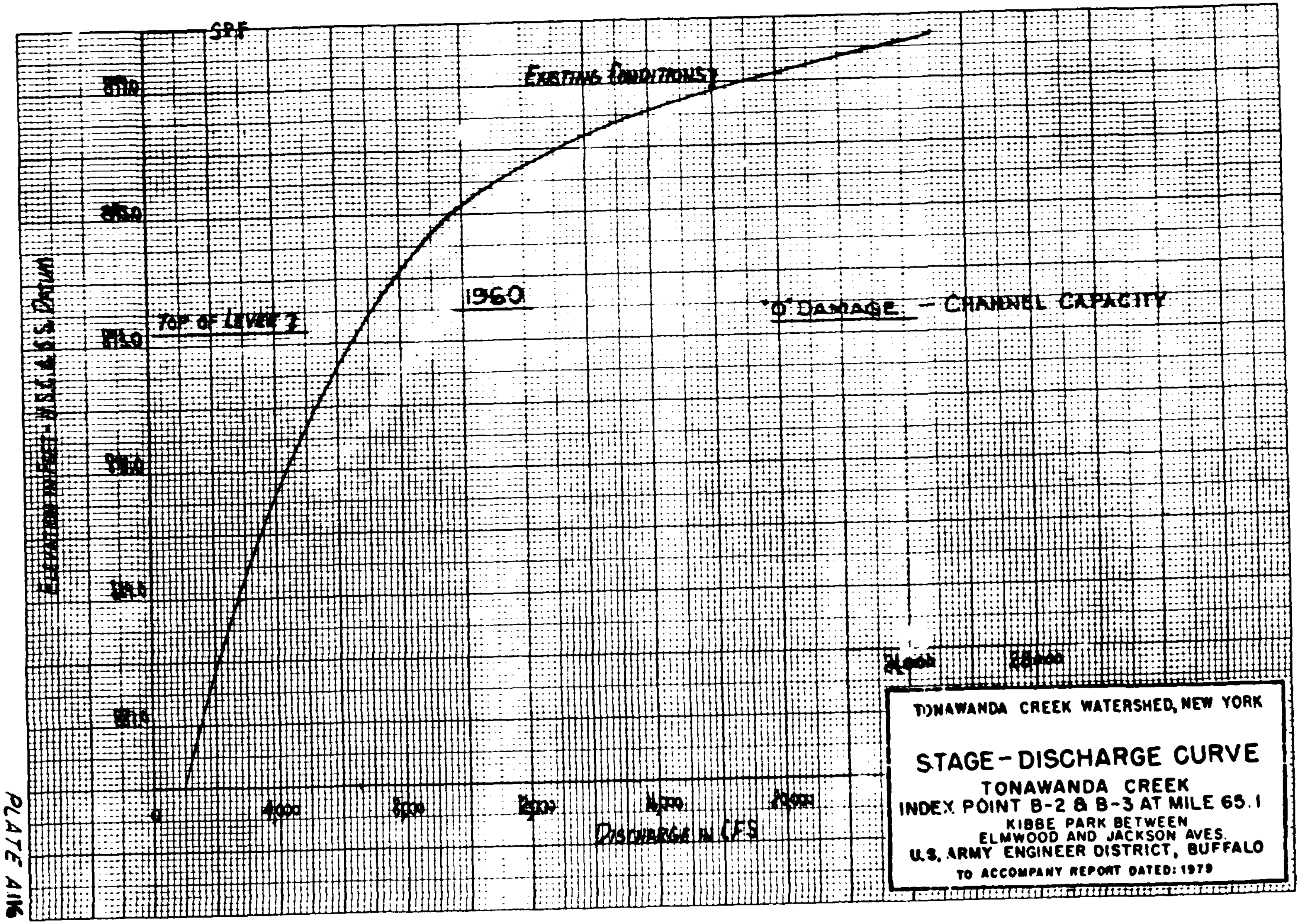
U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A115

K•E 10 X 10 TO ½ INCH
KEUFFEL & ESSER CO.

46 1320



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DISCHARGE CURVE

TONAWANDA CREEK

INDEX POINT B-2 & B-3 AT MILE 65.1

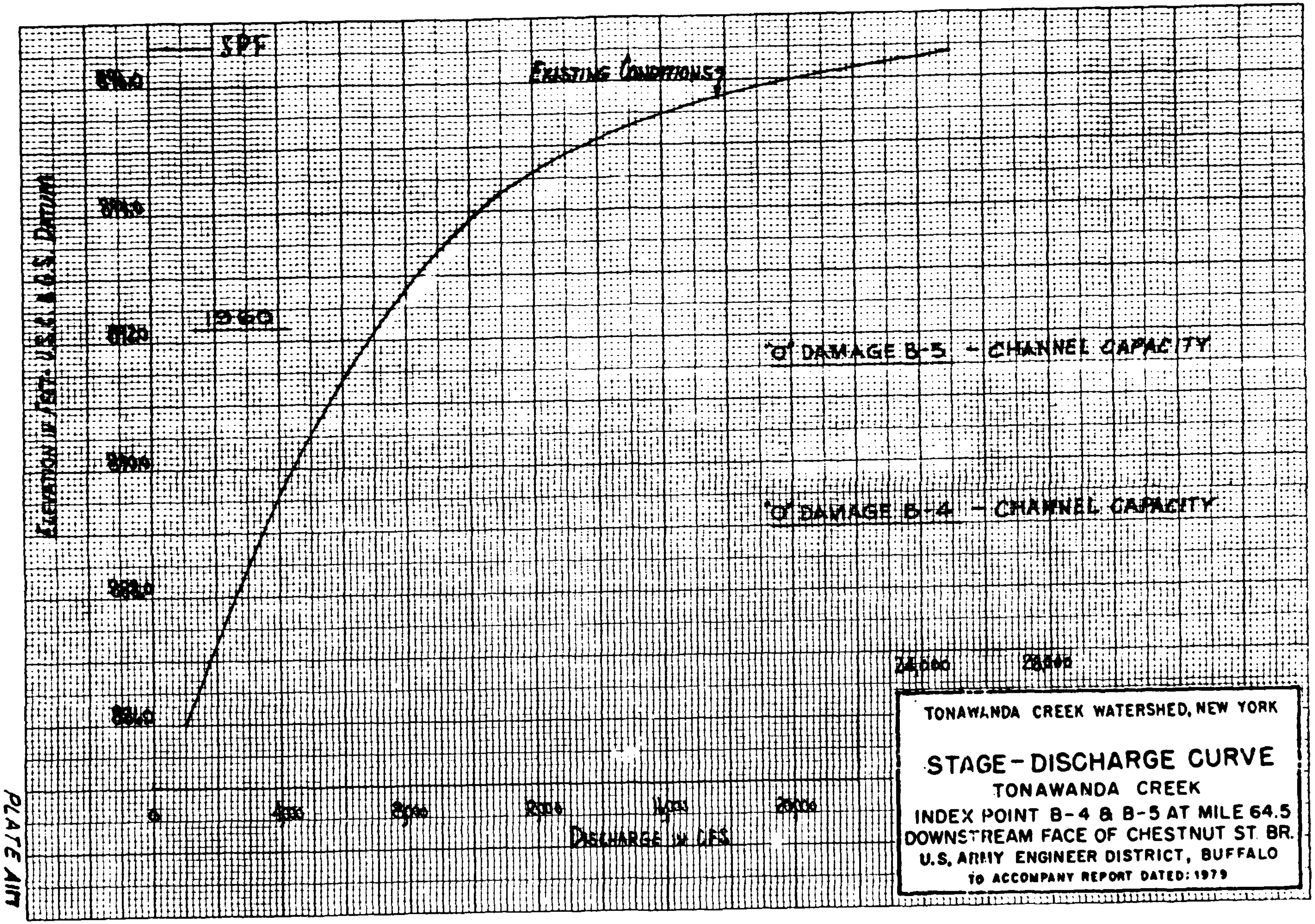
KIBBE PARK BETWEEN

ELMWOOD AND JACKSON AVES.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A116



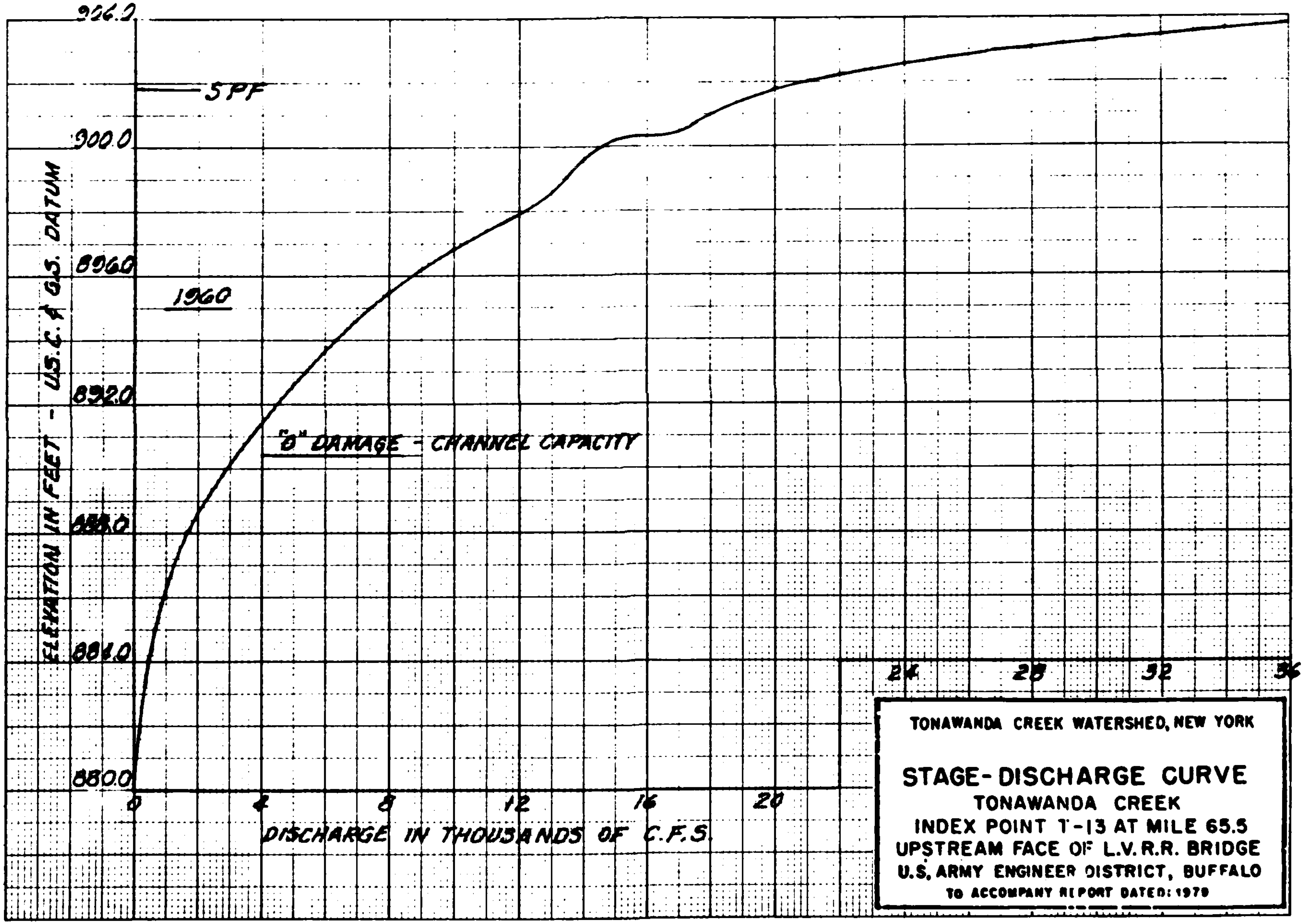
TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DISCHARGE CURVE

TONAWANDA CREEK

INDEX POINT B-4 & B-5 AT MILE 64.5
DOWNSTREAM FACE OF CHESTNUT ST. BR.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

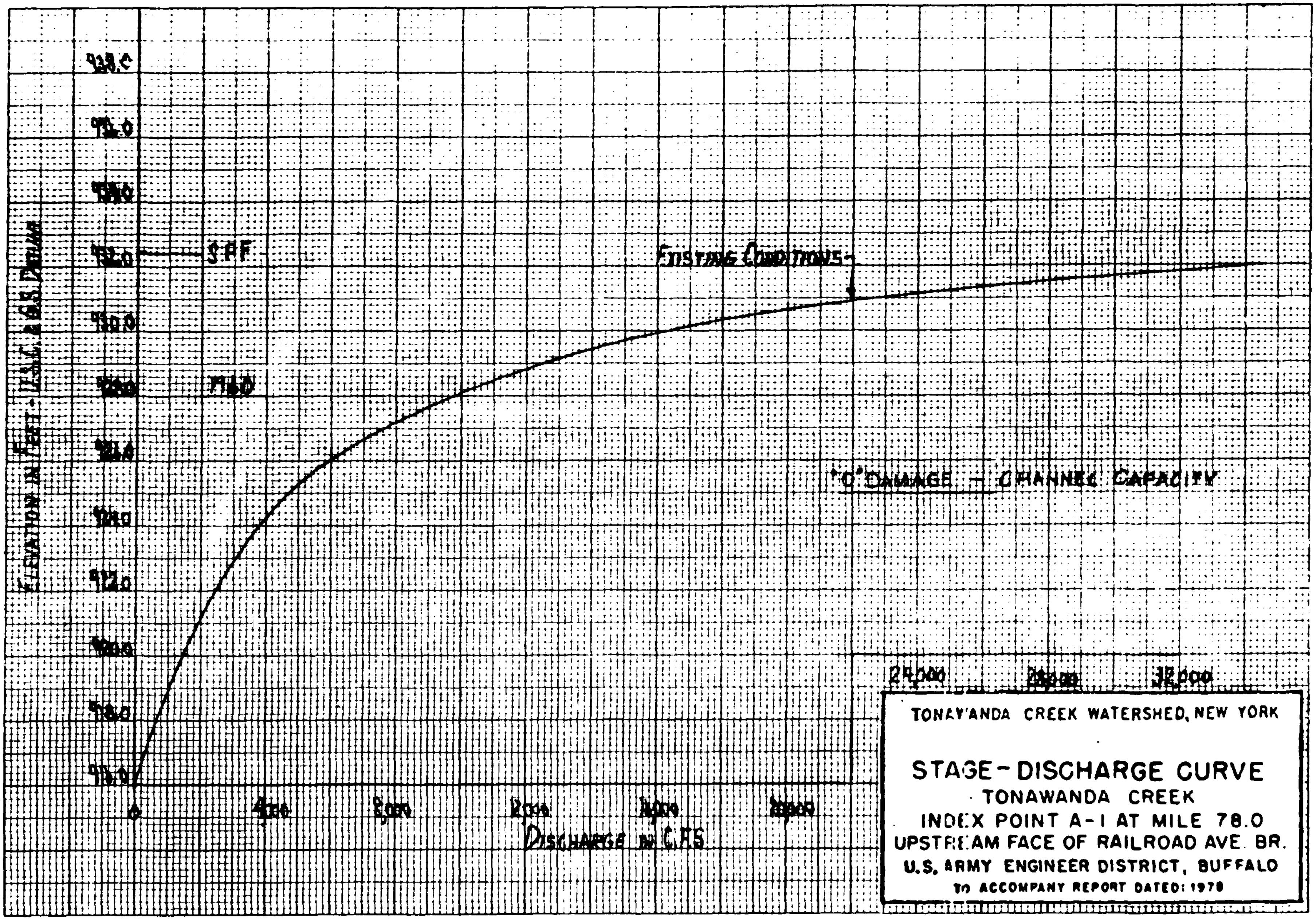
PLATE A17



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DISCHARGE CURVE
TONAWANDA CREEK
INDEX POINT T-13 AT MILE 65.5
UPSTREAM FACE OF L.V.R.R. BRIDGE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A118

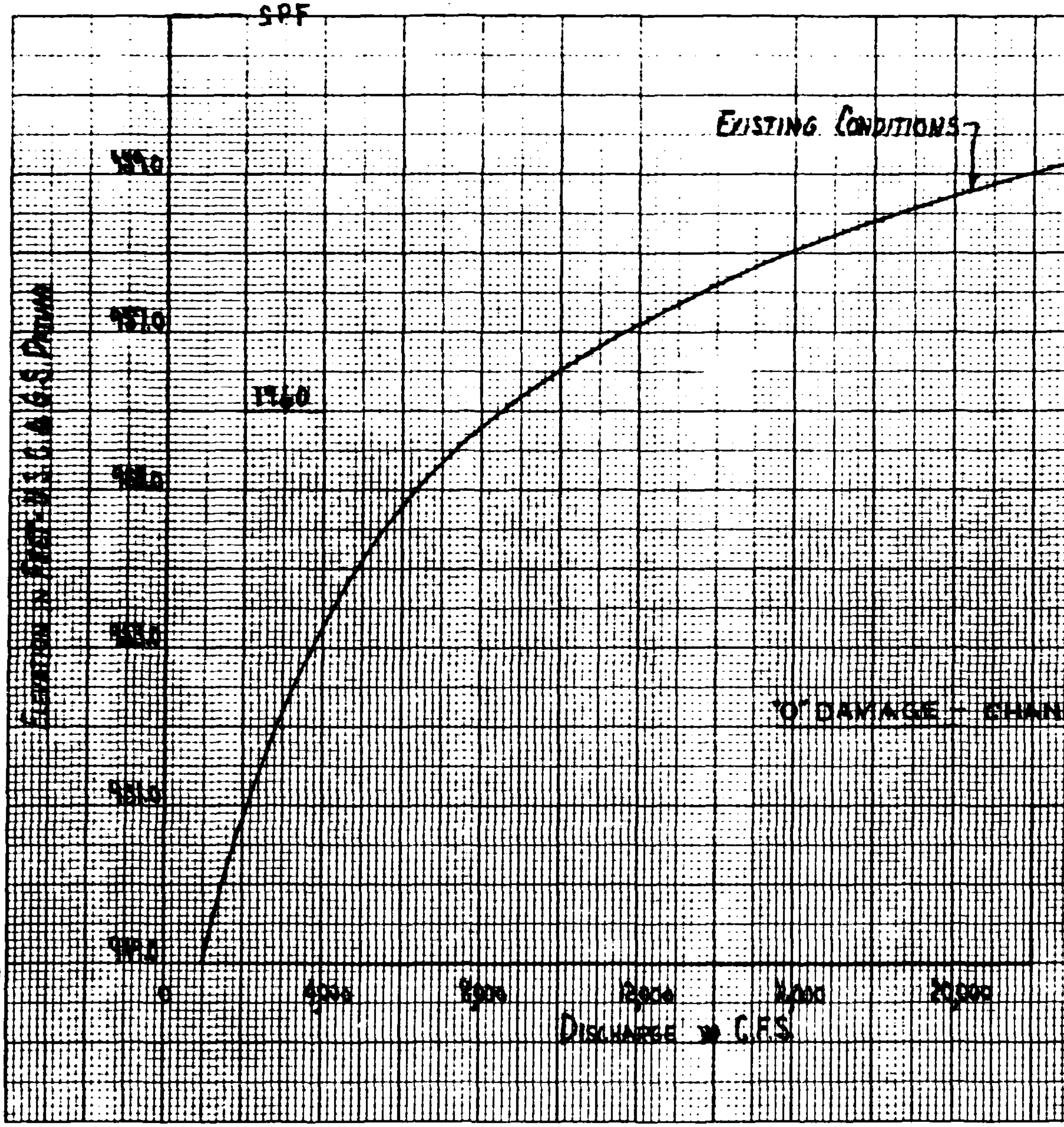


TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DISCHARGE CURVE
TONAWANDA CREEK
INDEX POINT A-1 AT MILE 78.0
UPSTREAM FACE OF RAILROAD AVE. BR.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1978

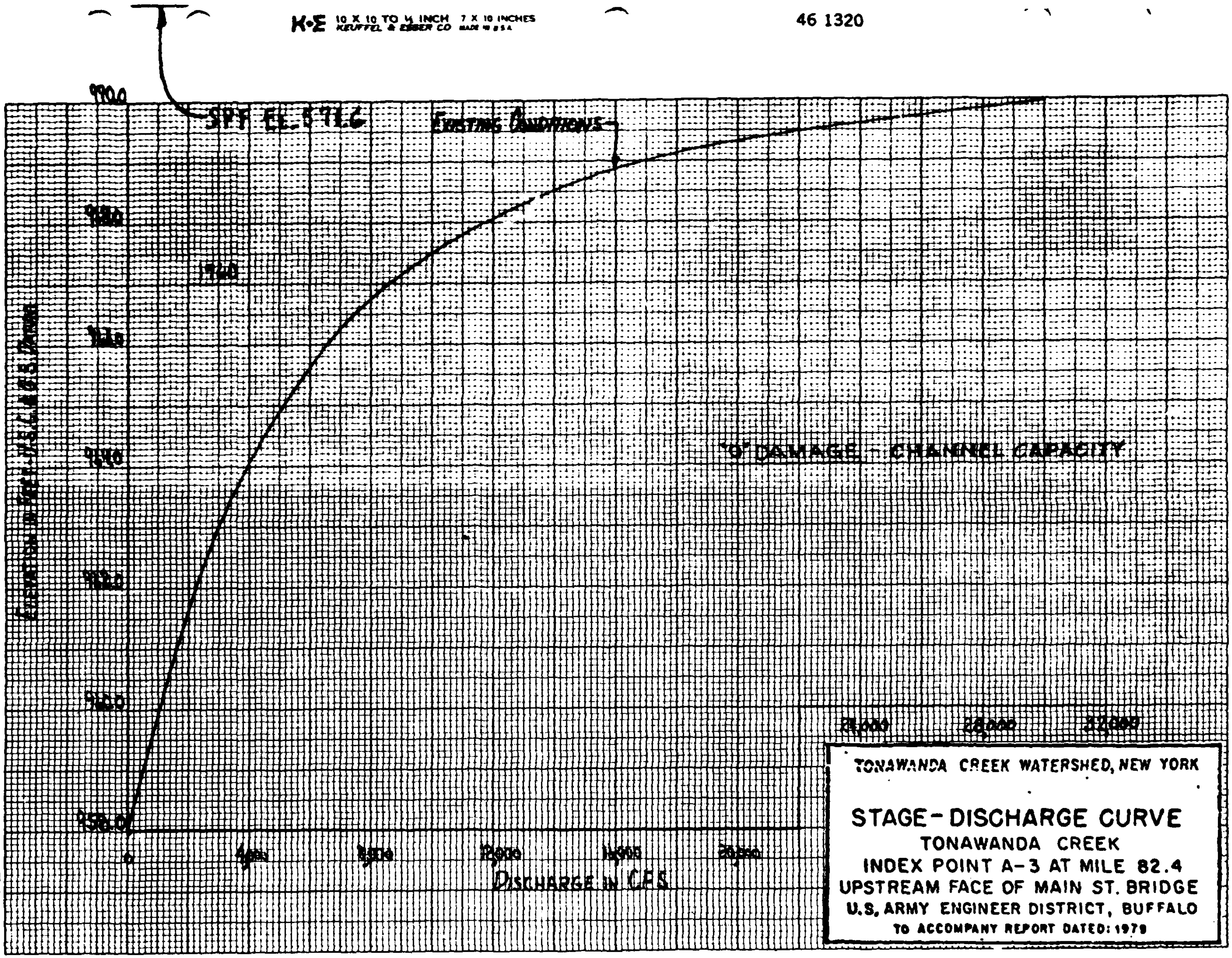
PLATE A119

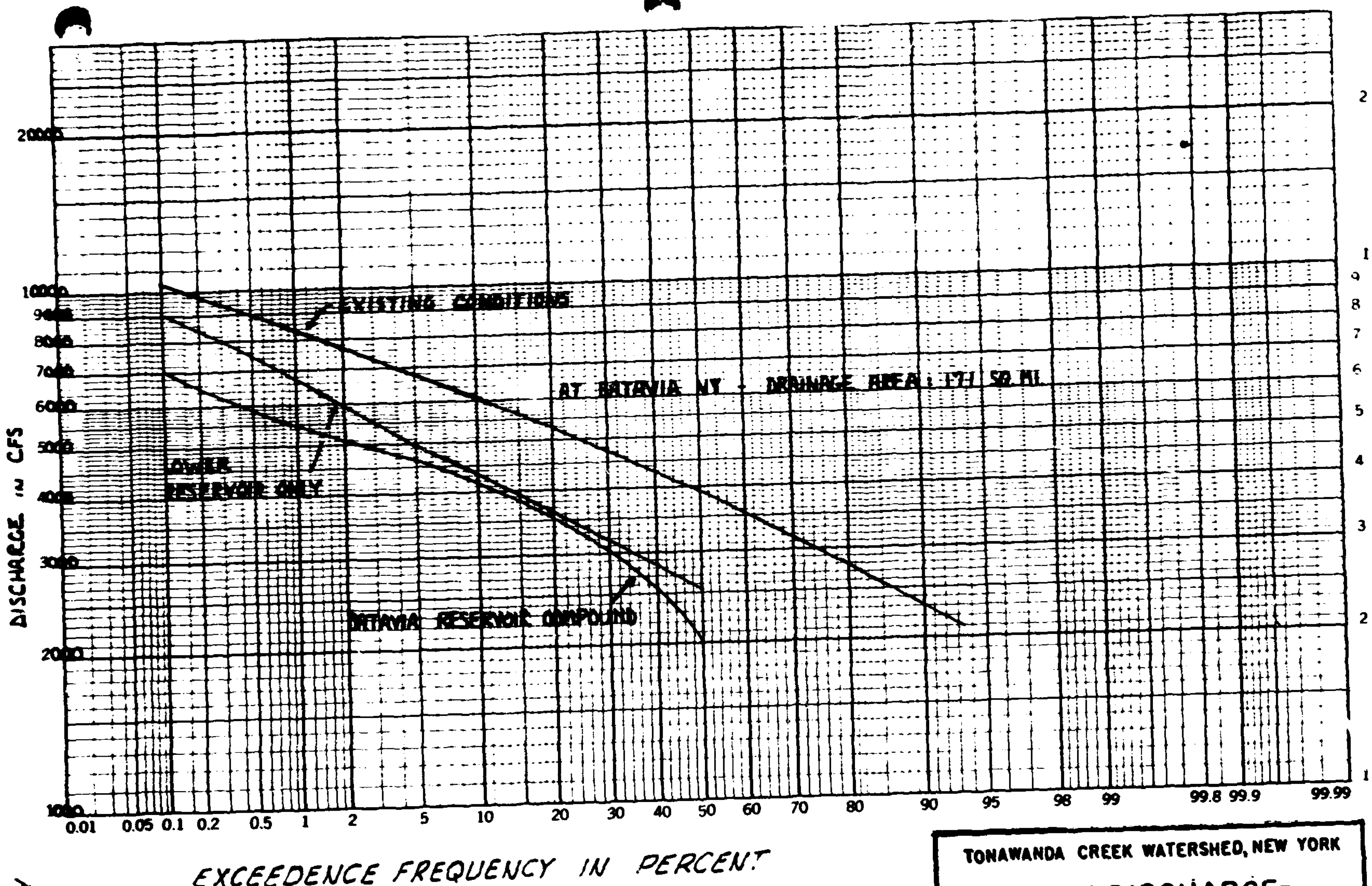
K•E 10 X 10 TO ½ INCH KEUFFEL & ESSER CO. 46 1320



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DISCHARGE CURVE
TONAWANDA CREEK
INDEX POINT A-2 AT MILE 81.6
UPSTREAM FACE OF PROSPECT ST. BR.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979


Existing Conditions
"0" DAMAGE - CHANNEL CAPACITY
0
4,000
8,000
12,000
16,000
20,000
24,000
28,000
32,000
DISCHARGE IN C.F.S.
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE - DISCHARGE CURVE
TONAWANDA CREEK
INDEX POINT A-3 AT MILE 82.4
UPSTREAM FACE OF MAIN ST. BRIDGE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

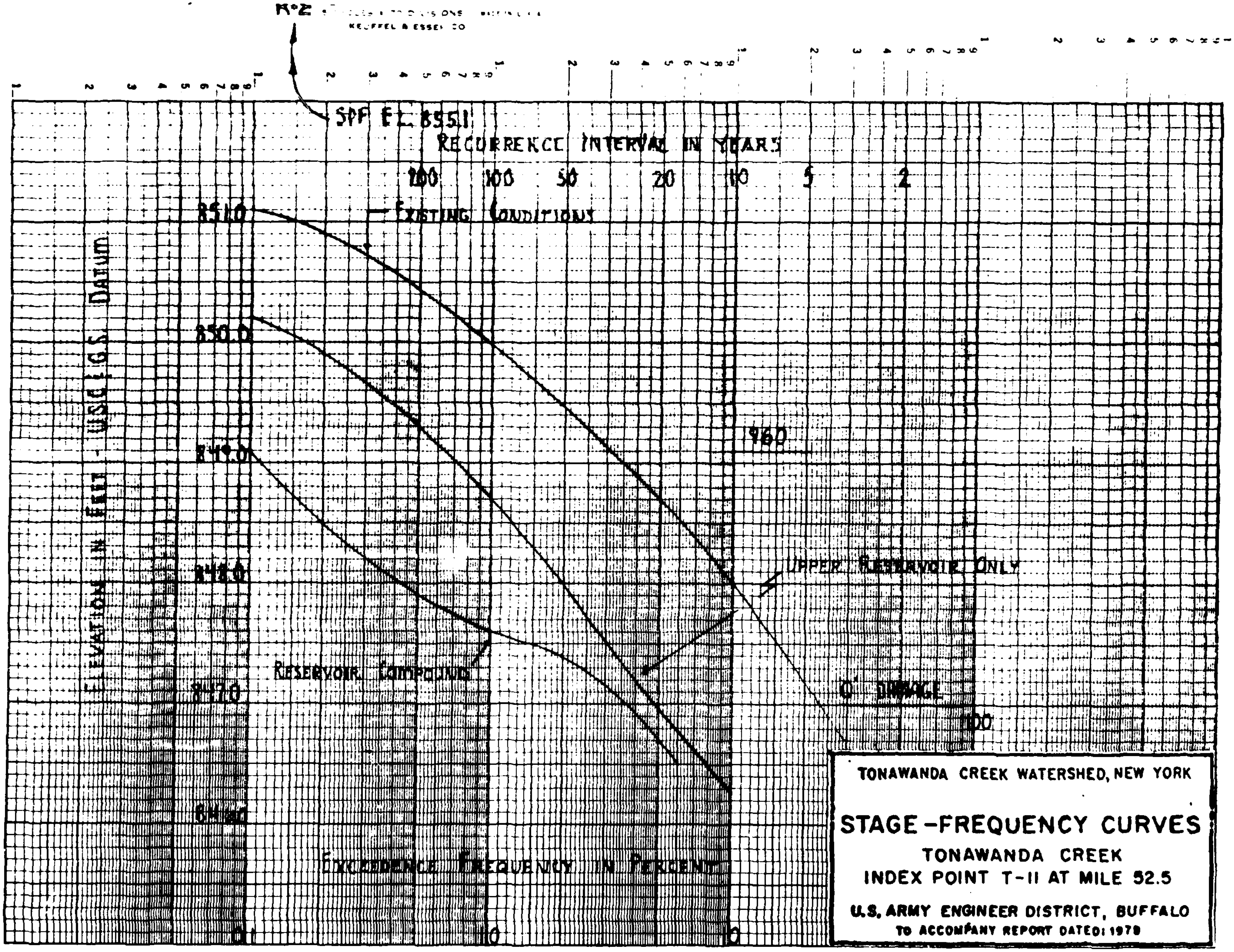
PEAK DISCHARGE-FREQUENCY CURVES AT BATAVIA GAGE

TONAWANDA CREEK

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE A122



TONAWANDA CREEK WATERSHED, NEW YORK

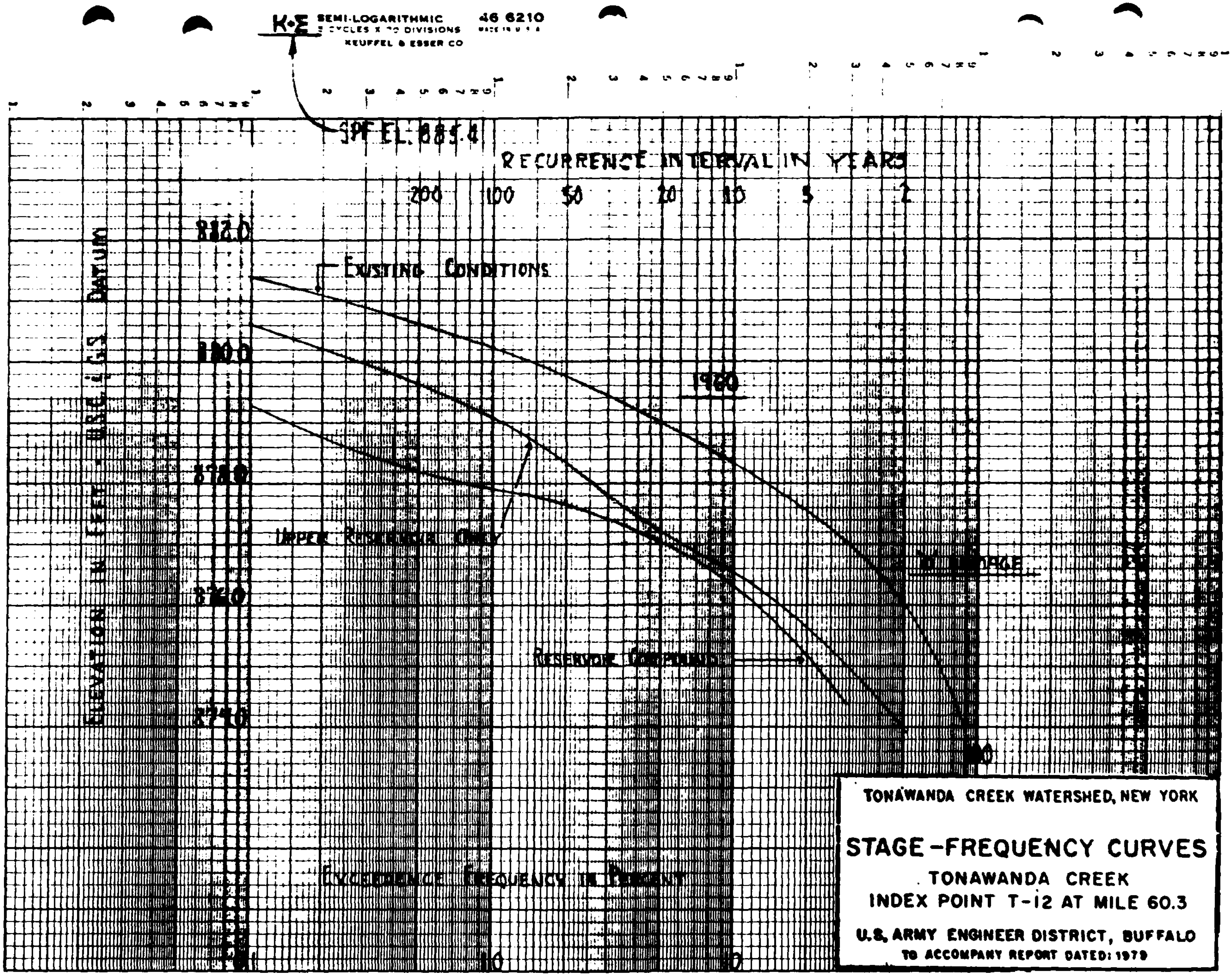
STAGE-FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT T-11 AT MILE 52.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

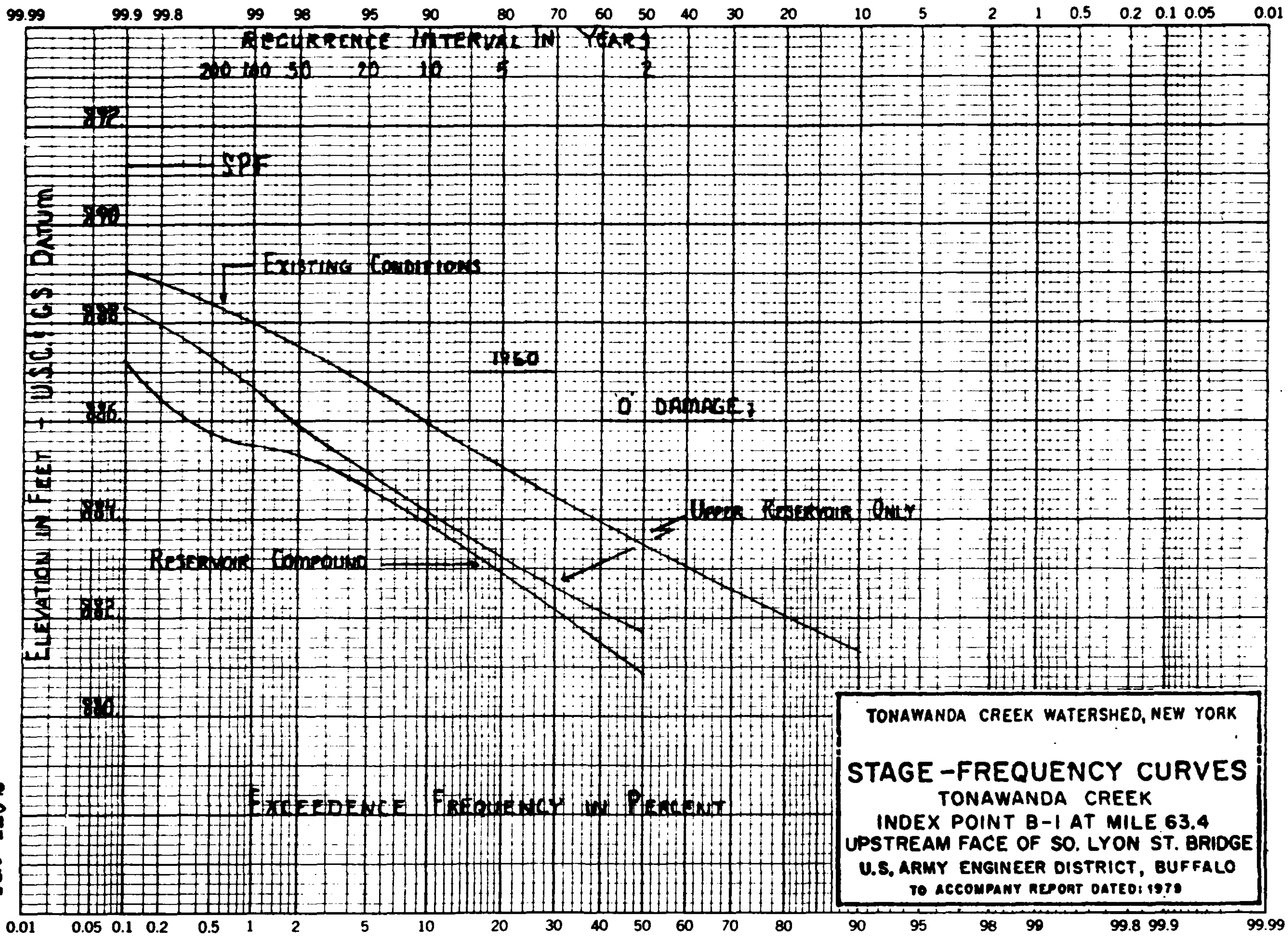
STAGE-FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT T-12 AT MILE 60.3

U.S. ARMY ENGINEER DISTRICT, BUFFALO

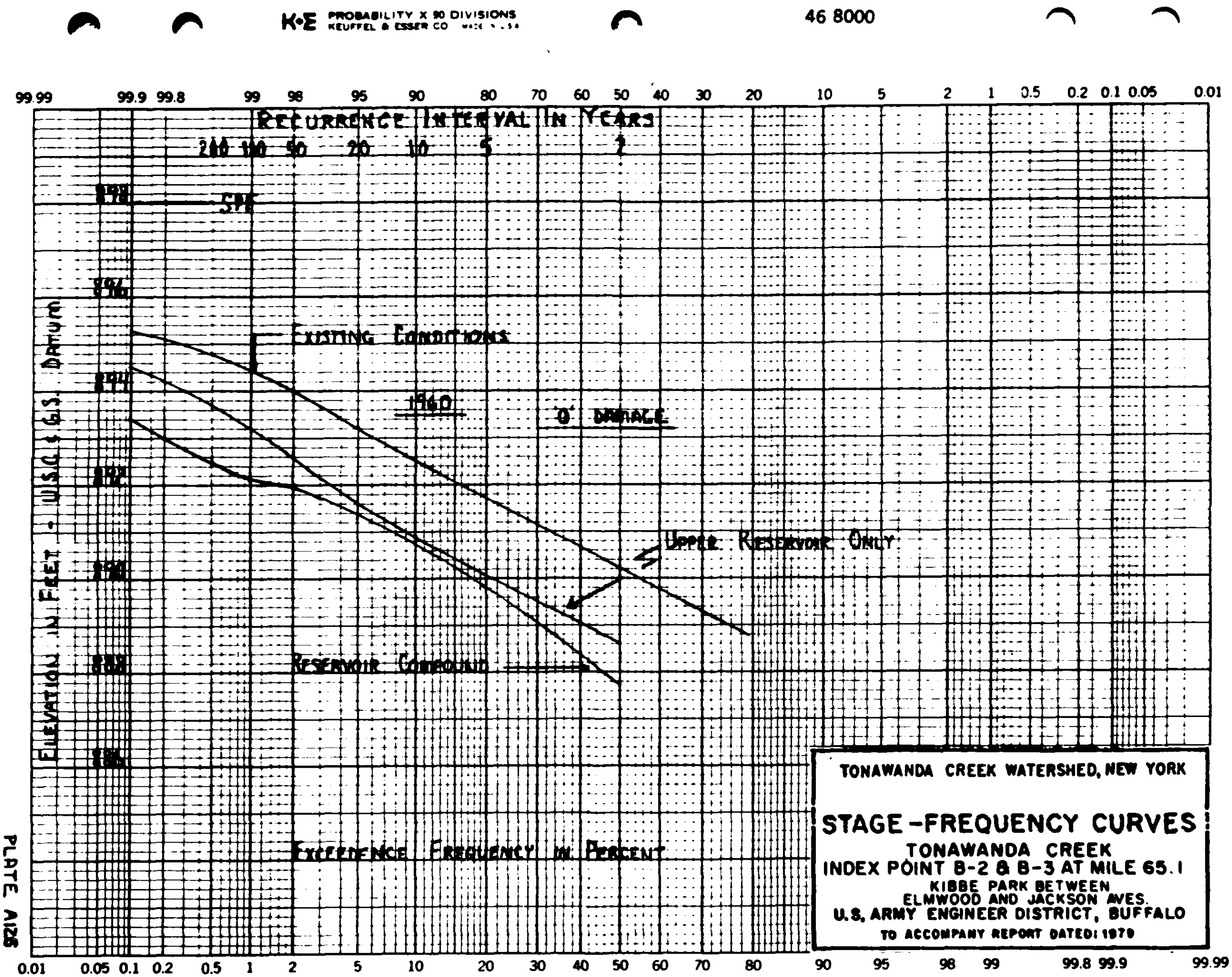
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

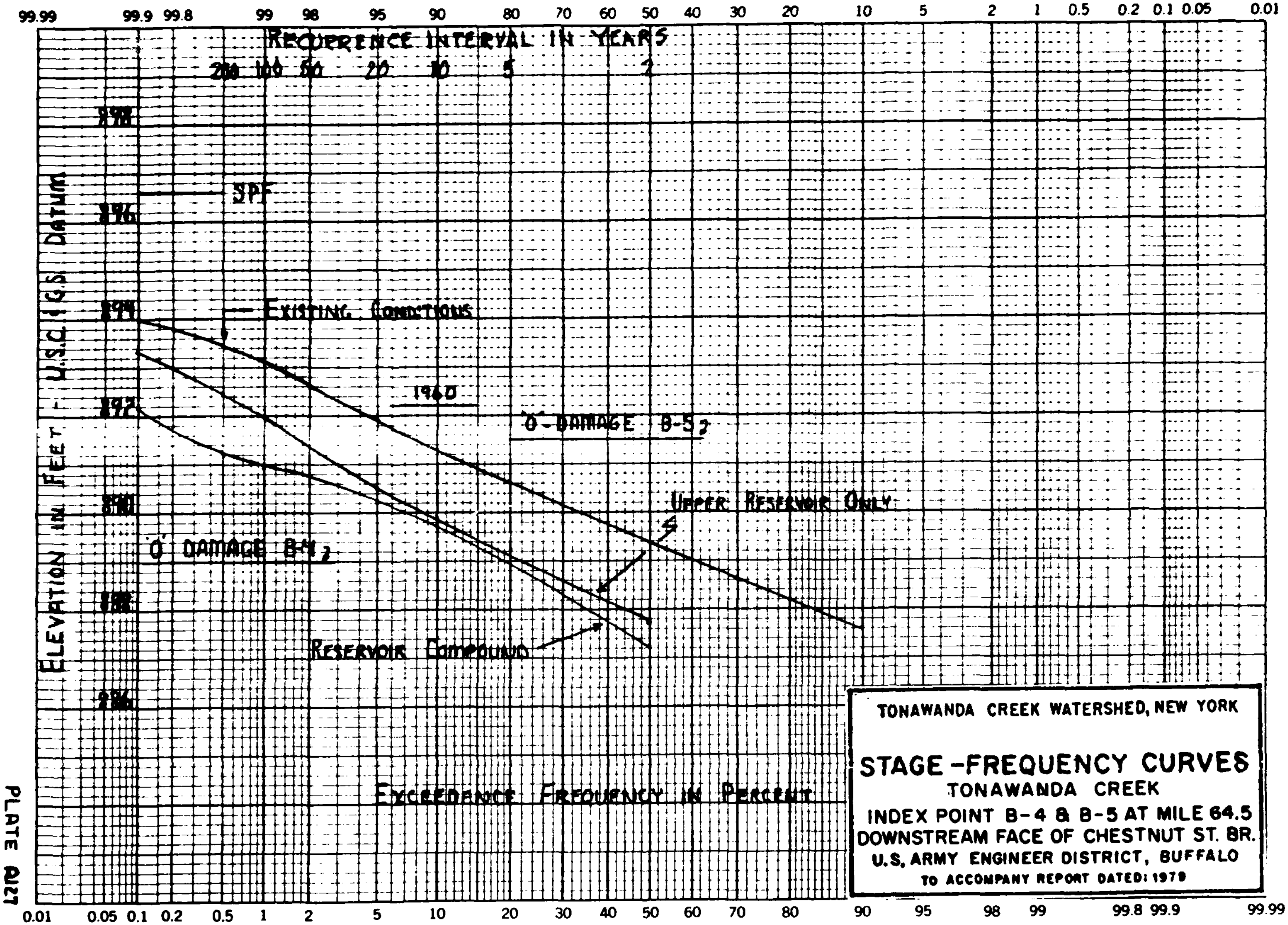
STAGE-FREQUENCY CURVES
TONAWANDA CREEK
INDEX POINT B-1 AT MILE 63.4
UPSTREAM FACE OF SO. LYON ST. BRIDGE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE AR5



K•E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO.
46 8000
RECURRENCE INTERVAL IN YEARS
200 100 50 20 10 5 2
SPF
EXISTING CONDITIONS
1960
0' DAMAGE
UPPER RESERVOIR ONLY
RESERVOIR COMPOUND
EXCEEDENCE FREQUENCY IN PERCENT
ELEVATION IN FEET - U.S.C.&G.S. DATUM
898
896
894
892
890
888
886
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-FREQUENCY CURVES
TONAWANDA CREEK
INDEX POINT B-2 & B-3 AT MILE 65.1
KIBBE PARK BETWEEN
ELMWOOD AND JACKSON AVES.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A126



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES

TONAWANDA CREEK

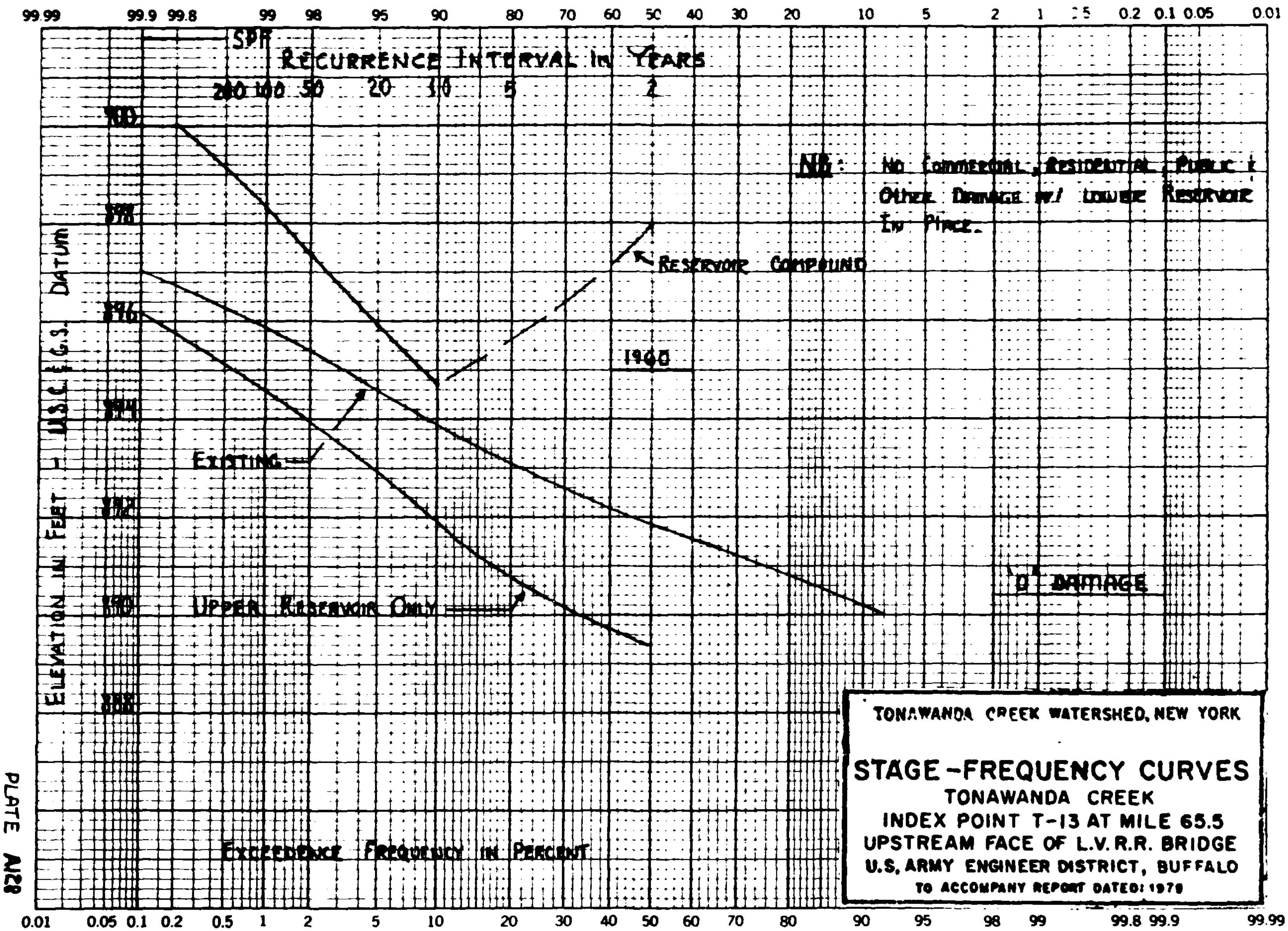
INDEX POINT B-4 & B-5 AT MILE 64.5

DOWNSTREAM FACE OF CHESTNUT ST. BR.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

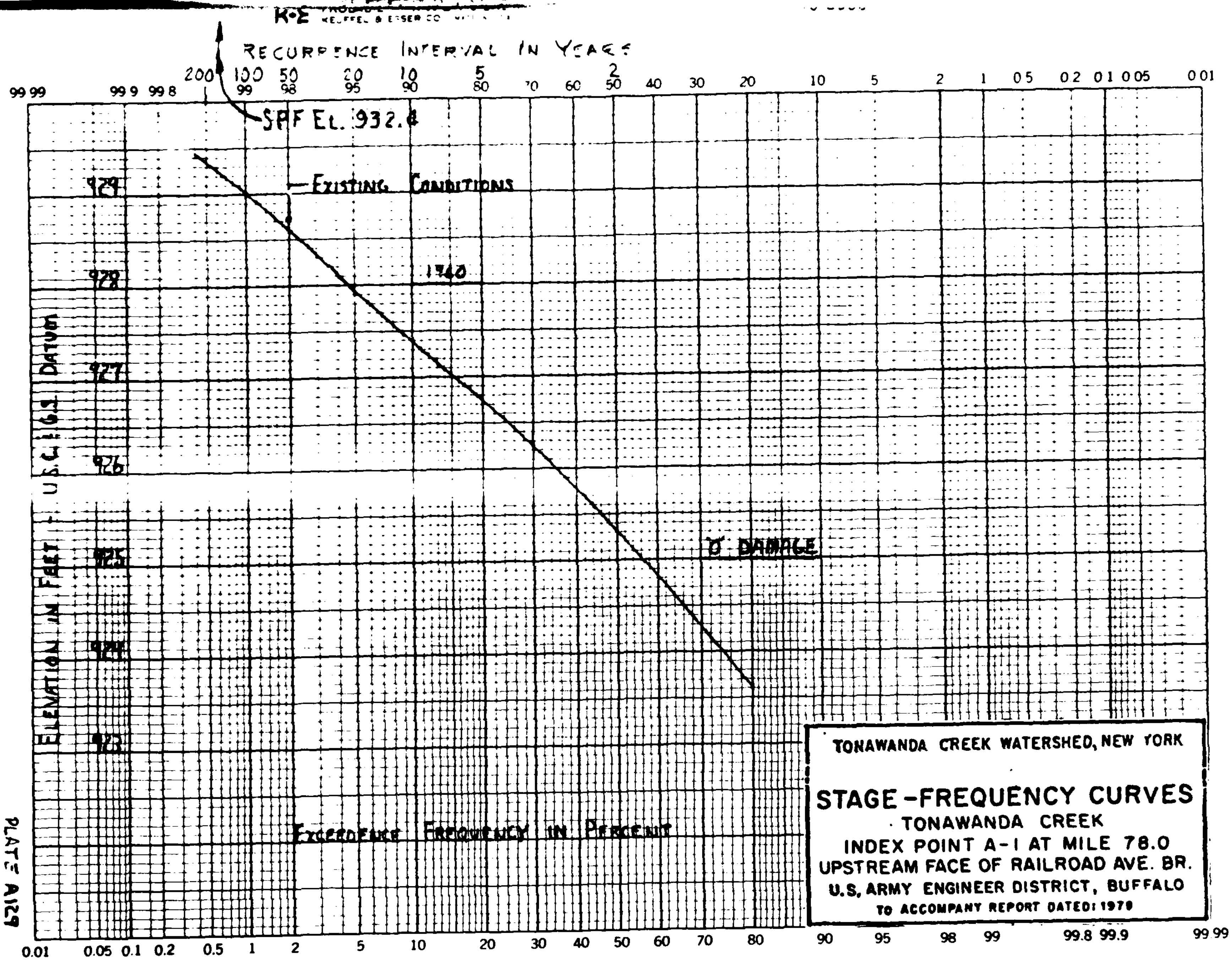
TO ACCOMPANY REPORT DATED: 1979

PLATE A127



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES
TONAWANDA CREEK
INDEX POINT T-13 AT MILE 65.5
UPSTREAM FACE OF L.V.R.R. BRIDGE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

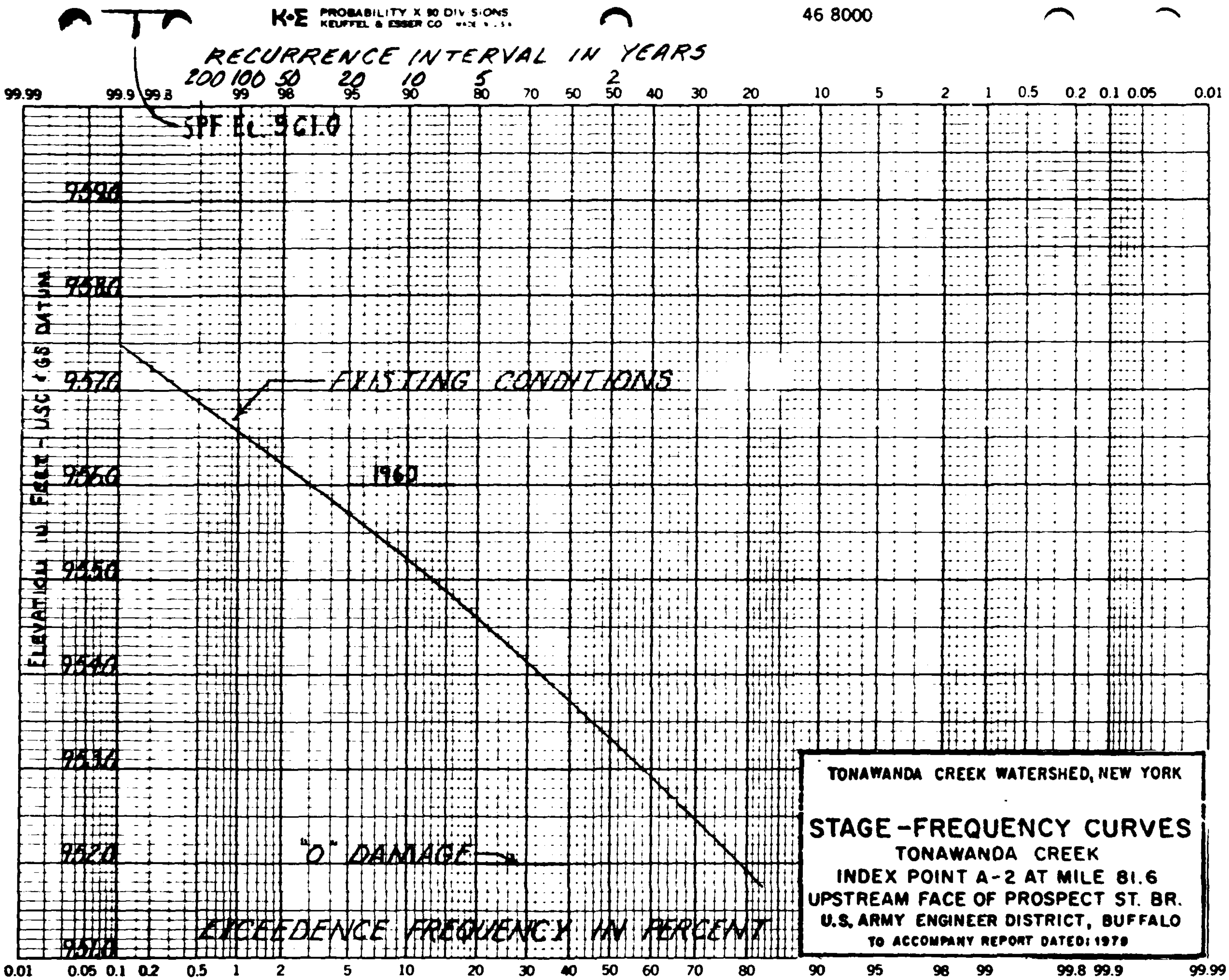


TONAWANDA CREEK WATERSHED, NEW YORK

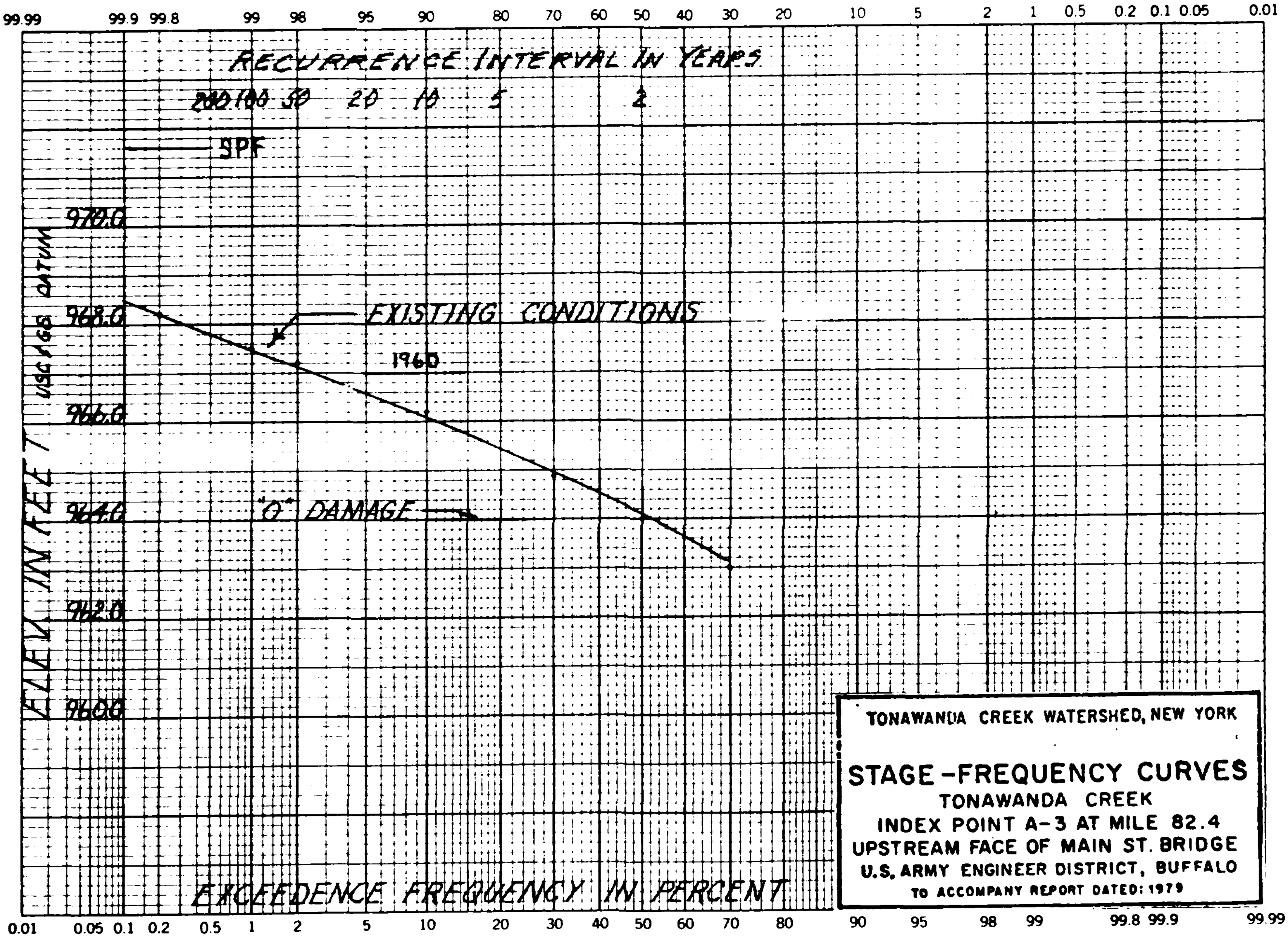
STAGE-FREQUENCY CURVES

TONAWANDA CREEK
INDEX POINT A-1 AT MILE 78.0
UPSTREAM FACE OF RAILROAD AVE. BR.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE A129



K•E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO.
46 8000
RECURRENCE INTERVAL IN YEARS
200 100 50 20 10 5 2
99.99 99.9 99.8 99 98 95 90 80 70 50 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
SPF EL 961.0
959.0
958.0
957.0
956.0
955.0
954.0
953.0
952.0
951.0
ELEVATION IN FEET - USC & GS DATUM
EXISTING CONDITIONS
1960
"0" DAMAGE
EXCEEDENCE FREQUENCY IN PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-FREQUENCY CURVES
TONAWANDA CREEK
INDEX POINT A-2 AT MILE 81.6
UPSTREAM FACE OF PROSPECT ST. BR.
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979



TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-FREQUENCY CURVES

TONAWANDA CREEK

INDEX POINT A-3 AT MILE 82.4

UPSTREAM FACE OF MAIN ST. BRIDGE

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

BUFFALO METROPOLITAN AREA, NY
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1980

APPENDIX B

FLOOD DAMAGES

AND

MANAGEMENT BENEFITS

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1976

APPENDIX B

FLOOD DAMAGES

AND

MANAGEMENT BENEFITS

Appendix B has been reproduced from the Interim Report on Feasibility of Flood Management in Tonawanda Creek Watershed (Volume II Appendices), 1976. Minor editorial changes have been made to improve the readability of the text materials. This document contains the basic evaluation of all considered plans of improvement including the recommended plan of improvement. The Selected Plan in 1976 was the Batavia Reservoir Compound (BRC) which consisted of two reservoirs to be located upstream of the city of Batavia, New York.

Review and comment on the BRC Plan resulted in the development of a new operation plan to be based upon new hydraulic and hydrologic information. The recommended plan has been designed as the Batavia Reservoir Compound - Modified (BRCM) and has been evaluated and summarized in Supplement S. Economic benefits attributed to the BRCM are based on June 1979 prices.

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

APPENDIX B

EVALUATION OF FLOOD DAMAGES AND BENEFITS

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TABLES (Cont'd)

PLATES

TABLE OF CONTENTS (Cont'd)

PLATES (Cont'd)

TABLE OF CONTENTS (Cont'd)

PLATES (Cont'd)

B1. THE AFFECTED AREA

B1.1 The area affected by the proposed Tonawanda Creek flood damage management project consists of the flood plain plus all other areas likely to serve as alternative sites for any activity which might use the flood plain if it were protected. Determination of the affected areas for this flood management study was based upon an analysis of existing development in the Tonawanda Creek Watershed which provided an insight to potential future uses of the flood plain.

B1.2 The Tonawanda Creek Watershed, an area of approximately 648 square miles, is located in western New York and includes substantial portions of Erie, Niagara, Genesee and Wyoming Counties in addition to a minor part of Orleans County. The political subdivisions of the watershed, in addition to climatological and hydrologic stations, are shown on Plate B1. Economic growth in the Buffalo urban area, originally stimulated by Buffalo's historical geographic position as a break-bulk transshipment point for Great Lakes cargo, has induced considerable development in the western portion of the watershed. Towns and villages that were once outside Buffalo have lost their separate identity as suburbanization has spread outward from the city. Development of improved waterway and highway transportation networks has accelerated this expansion and transformed outlying semi-rural areas such as Amherst and Clarence, NY, into growing suburban communities. Analysis of past and present trends indicates that the process of conversion of agricultural and vacant land into residential land use is spreading to the northeast and east of Buffalo, NY, in Erie County. A significant factor in establishing these trends was the major highway construction of the 1960's which reduced the commuting times significantly to the major employment centers.

B1.3 Much of the western portion of the watershed is directly in the path of these growth corridors. Vacant land in the Ellicott and Tonawanda Creek flood plains is now under pressure to develop into residential subdivisions. The new State University campus and two planned communities in Amherst are already inside flood hazard zones. These developments should act as nodal points for future development in Amherst. Lands in the northern portions of Amherst and Clarence adjacent to Tonawanda Creek consist of idle vacant land with minimal vegetative cover or lands actively farmed, either on a full or part-time basis. Large amounts of open farmland have already been taken out of production in this area as a result of land speculation.

B1.4 The Buffalo Metropolitan Area is the largest industrial and commercial center in Upstate New York. Its highway network, large supply of skilled labor, access to raw materials, ample electric power, and ready access to markets in the northeast, midwest, and Canada have all contributed to the region's economic development. Almost all of the development in the western portion of the watershed can be attributed to growth in the Buffalo Metropolitan Area. Remaining areas of the watershed are primarily agricultural, however, the Tonawanda Indian Reservation and three extensive wildlife refuges also occupy areas of significant size near the center of the watershed. A secondary manufacturing, commercial and institutional growth

center in the watershed is the city of Batavia, located in Genesee County. Table B1 lists the major population centers, by county, in the watershed.

B1.5 Existing land use patterns in the Tonawanda Creek flood plain and adjacent areas are depicted in Plate B2. Portions of the watershed included in Erie and Niagara Counties are coming under increasing pressure to accommodate the Buffalo urban area's demand for development of land: commercial, institutional, residential, recreation, and open space. Future estimates of the outer limits of the Buffalo Metropolitan Area have been liberally estimated by regional and local planning agencies to extend outward to the eastern boundary of the town of Clarence, about 13 miles from the center of Buffalo. The area included within a 13-mile radius of the Buffalo CBD also includes undeveloped acreage in other first and second-ring suburban towns which is less distant from the CBD than portions of Clarence or Amherst. These alternate areas are also expected to experience further population growth.

B1.6 Land in Genesee and Wyoming Counties is used primarily for agriculture, although the manufacturing sector accounts for the largest portion of total employment. Almost 286,000 acres within the watershed, slightly less than 450 square miles, are farmlands. Of this amount, 108,000 acres are designated by State or regional planning agencies as high viability farmlands. High viability farmland is acreage which is extremely productive or suitable for cultivation of a crop which is of high quality and/or not easily produced elsewhere in the State. Several agricultural districts, formed in the upper reaches, should help to maintain the future of active agriculture and discourage the conversion of productive land into nonfarm uses.

B1.7 Economic and social activity upstream of the Indian Reservation is concentrated in the city of Batavia. Batavia's geographic location midway between Rochester and Buffalo has been a major factor in its cultural and economic dominance of the area. Batavia is in the midst of a rich farm and industrial region and serves as a major center of motor freight service and is a growing wholesale distribution point. Growth in the Batavia area should continue at its present moderate rate. However, this expansion will probably occur outside the city limits but in the town of Batavia. Historically, when sufficient land was available, development was centered inside the city but the growing scarcity of open areas suitable for urban development will redirect future growth to areas outside the city limits.

B1.8 The type and extent of social and economic activities within the flood plain indicates that the area affected by the proposed project would include Erie, Niagara, Genesee and Wyoming Counties. Any activity which might locate in the lower Tonawanda Creek flood plain (Erie and Niagara Counties) would have many locational options available in either county. Therefore, the two county Buffalo SMSA was designated as the affected area for that portion of the watershed downstream of the Indian Reservation. The eastern part of the Tonawanda Creek Watershed is predominately agricultural with manufacturing and commercial activity centered in Batavia. Approximately 62 percent of the total area in Genesee and Wyoming Counties was actively used for agriculture in 1969. Since farm activities can be

Table B1 - Tonawanda Creek Watershed
Historical Population of Political Subdivisions

Towns	1940	1950	1960	1970
Erie County				
City of Tonawanda	6,440	14,617	21,561	21,898
Town of Amherst	19,532	33,744	62,837	93,929
Town of Clarence	4,402	6,331	13,267	18,168
Town of Newstead	1,516	4,653	5,825	6,322
Town of Tonawanda	65,000	55,270	105,032	107,282
Niagara County				
City of North Tonawanda	20,256	24,731	34,757	36,012
Town of Lockport	3,179	3,945	6,492	8,177
Town of Pendleton	1,516	1,815	3,589	4,733
Town of Royalton	4,626	5,297	6,585	7,375
Town of Wheatfield	3,060	4,720	8,008	9,722
Genesee County				
City of Batavia	17,267	17,799	18,210	17,338
Town of Alexander	1,423	1,591	1,987	2,351
Town of Batavia	2,261	2,824	4,325	5,440
Town of Pembroke	2,391	2,866	3,451	3,959
Town of Alabama	1,763	1,766	1,931	1,872
Wyoming County				
Town of Attica	2,387	5,722	5,781	6,171

Source: Business Fact Book, Part 2, 1974 Edition, New York State Department of Commerce

practiced over extensive areas of both counties, the two-county area was delineated as the affected area for agricultural activities upstream of the Tonawanda Indian Reservation.

B1.9 Twenty-four percent of the 1970 population of the two upstream counties was located in the towns of Batavia and Attica - the remainder of the population resided in outlying towns or villages. This wide dispersion of the rural population indicates that the affected area for future residential activity should also consist of Genesee and Wyoming Counties. Commercial and industrial activity in the upper watershed is concentrated in the city of Batavia, therefore this city was delineated as the affected area for future commercial activity in Genesee and Wyoming Counties.

B2. PROJECTED DEMOGRAPHIC AND ECONOMIC ACTIVITIES IN THE AFFECTED AREA

B2.1 Projections of demographic and economic activity within the affected area were assumed independent of any flood management project. The following characteristics were projected to 2030: population, employment, manufacturing employment, per capita income, commercial employment and agricultural output.

a. Population.

B2.2 Historical population changes between 1920 and 1970 are presented in Table B2. Historical population shifts have served as the basis for projecting the level of future population. Numerous sources, including State and Federal agencies, have made projections of future population levels. Most of the counties, with the exception of Wyoming, have already been incuded for analysis by larger regional planning agencies such as the Erie and Niagara Counties Regional Planning Board (ENCRPB) and the Genesee/Finger Lakes Regional Planning Board. Countywide sewerage studies of Genesee and Wyoming Counties completed in 1970 were also major sources of information for future levels of economic activity in the area.

Table B2 - Historical Population Trends for Selected Areas1/
(in Thousands)

	1920	1930	1940	1950	1960	1970
New York State	10,385.6	12,588.1	13,479.1	14,830.2	16,782.3	18,241.3
Erie County	634.7	762.4	798.4	899.2	1,064.7	1,113.5
Town of Amherst	6.3	13.3	19.5	33.7	62.8	93.9
Niagara County	118.7	149.3	160.1	190.0	242.3	235.7
City of North Tonawanda	15.5	19.0	20.3	24.7	34.7	36.0
Genesee County	38.0	44.5	44.5	47.6	54.0	58.7
City of Batavia	11.6	17.4	17.3	17.8	18.2	17.3
Wyoming County	30.3	28.8	31.4	32.8	34.8	37.7
Town of Attica	0.7	0.7	3.1	5.7	5.8	6.2
Village of Attica	2.0	2.2	2.4	2.7	2.8	2.9

1/ Including institutions.

SOURCE: U. S. Bureau of the Census, material compiled by New York State Department of Commerce

B2.3 Within the watershed, the area of greatest population change between 1960 and 1970 was Erie County, Table B3, while the highest rates and growth occurred in Genesee and Wyoming Counties. Population density within the watershed increases as one proceeds downstream to the creek's confluence with the Niagara River. Historically, the greatest population increase in the rural areas of the watershed has been centered in the village and town of Attica and the city of Batavia. Together these three municipal areas contributed between 21 percent and 33 percent of the combined population of Genesee and Wyoming Counties during the period 1920 to 1970.

Table B3 - Demographic Statistics
Population, Rank, Density,
and Area of Selected Counties

County	Population: April 1, 1960	Population: April 1, 1970	Change from April 1960 to April 1970: Number	Change from April 1960 to April 1970: Percent	Per Sq. Mile	Land Area in Square Miles
Erie	1,064,688	1,113,491	48,803	+4.6	1,052.	1,058
Niagara	242,269	235,720	-6,549	-2.7	443.	532
Genesee	53,793	58,722	4,728	+8.8	117.	501
Wyoming	34,793	37,688	2,895	+8.3	63.	598

SOURCE: U. S. Bureau of Census, Census of Population, Material compiled by New York State Department of Commerce.

B2.4 However, since 1940 the relative importance of these three population centers has declined. This trend has also been substantiated by a comprehensive sewage study for Wyoming County completed in 1970 which found a relatively constant population within the villages but population growth (between 1950 and 1970) outside these three urban centers. This trend is most likely attributed to the saturation of the land area contained within these three established towns. Future population growth can reasonably be expected to occur very near these three areas since most of the municipal facilities (sewer, water supply and storm water drainage systems) have already been installed.

B2.5 Genesee and Wyoming Counties are under the economic umbrella of the Buffalo and Rochester SMSA's. These two economic centers had a combined population in 1970 of more than 2.3 million residents and provided employment for over 874,800 people. The effects of population growth in either or both of these SMSA's will impact on the watershed's residents. An understanding of historical population growth in these large SMSA's will provide an insight into the extent of future population growth anticipated for Genesee and Wyoming Counties.

B2.6 Historically, the greatest increase in population has occurred in the Rochester SMSA located to the east of the watershed. A substantial population increase occurred in the Buffalo SMSA during the 1950's but population growth has subsequently leveled off to a three percent rise over the past decade, Table B4. Erie and Niagara Counties have experienced a pattern of change similar to other metropolitan areas. Population in the major cities declined (13 percent in the Buffalo and 16 percent in Niagara Falls), while smaller communities and unincorporated areas experienced large increases. After 1960, the population of the Rochester SMSA grew at a greater absolute and relative rate than the Buffalo area.

Table B4 - Standard Metropolitan Statistical Areas Historical Population Shifts in Buffalo and Rochester (in thousands)

	1900	1910	1920	1930	1940	1950	1960	1970
Buffalo SMSA	509	621	753	912	958	1,089	1,307	1,349
Total Change		112	132	159	46	131	218	42
Percentage Change		22%	21%	21%	5%	14%	20%	3%
Rochester SMSA	383	456	519	595	613	675	801	962
Total Change		73	63	76	18	62	126	20
Percentage Change		19%	14%	15%	3%	10%	19%	20%

SOURCE: New York State Statistical Yearbook - 1974, New York State Department of Commerce.

(1) Buffalo Standard Metropolitan Area

B2.7 The two county Buffalo SMSA had a 1970 population of 1,350,000. More than 80 percent of this total was located in Erie County which had a population density of 1,052 per square mile. This figure is twice the population density of Niagara County. Population in this SMSA is concentrated in an urban belt, which fronts on the Niagara River and Lake Erie, located along the western borders of Erie and Niagara Counties. The area's population center is the city of Buffalo which included 462,800 residents in 1970, or 42 percent of Erie County's population. The center of population is anticipated to shift into the first- and second-ring communities as the overall population of the metropolitan area remains the same. The city of Buffalo population is projected to decline to at least 400,000 by 1980, at the same time second- and third-ring towns will be growing in population. This population shift will place heavy demands for land in adjacent suburbs.

(2) Rochester Standard Metropolitan Area

B2.8 The Rochester area borders on the southern shore of Lake Ontario in New York State's upstate heartland, encompassing two of the larger and

four of the smaller Finger Lakes. Among the upstate economic areas, it ranks first in income and second in population. The city of Rochester is the business and cultural hub of the region, but there are also several smaller commercial centers throughout the district. In 1970, the nine county Rochester Area included over 1,110,000 residents; 64 percent of these people lived in Monroe County. Between 1960 and 1970, population in the area grew by 18 percent, with Monroe County accounting for 126,000 of the overall increase of 173,000. Compared with upstate areas, Rochester ranked first in total growth and second in percentage growth. Monroe County led all other upstate counties in absolute growth and in population density.

B2.9 Population projections developed by State and local agencies were reviewed and compared to Series E OBERS projections to determine the extent of deviation from baseline Series E data. Series E data was expressly developed by the Bureau of Economic Analysis for use by the Water Resources Council to satisfy a need for basic economic information by public agencies engaged in comprehensive planning for the use, management, and development of the nation's water and related resources.

B2.10 Population levels for the Buffalo SMSA are based upon Series E data. Population projections prepared by other regional planning agencies were also compared with OBERS projections. However, in the year 2030 there was only a minimal difference between the most conservative and liberal estimates. Therefore, OBERS data was considered an accurate representation of the Buffalo SMSA's growth potential. Series E projections for the Rochester SMSA were also compared with New York State Office of Planning Services (NYSOPS) Demographic Projections for New York State (Revised 6/74). There was only a deviation of four percent from Series E data. NYSOPS data was also utilized by the Genesee/Finger Lakes Regional Planning Board for estimating future populations. Due to this slight deviation from Series E and the consistency gained by using the same statistical series for both major SMSA's, Series E data was the main source of baseline economic data for large economic areas.

B2.11 Future population levels for Genesee County are based on revised NYSOPS projections. This series was revised downward in June 1974 and was recently referenced in Comprehensive Regional Development Plan published in June 1975 by the Genesee/Finger Lakes Regional Planning Board. Their region of study included Genesee County. NYSOPS was also the major source of data for projected economic activity within Wyoming County. Historical and projected population by decade is included in Table B5.

b. Employment.

(1) Erie and Niagara Counties

B2.12 Future employment was derived by application of an employment-population ratio (EPR) to projected population levels. The EPR is defined as the percentage of the population within an area which is employed. The historical trend of the EPR in the Buffalo SMSA was used to guide the estimates of future employment levels. Future employment in Genesee County was developed using the predicted trend of the EPR for Subarea 0413 since several

Table B5 - Projected Population for Selected Areas

	1970	1980	1990	2000	2010	2020	2030
Genesee County	58,722	64,464	70,935	75,709	83,936	93,033	101,433*
City of Batavia 1/	17,338	19,706	20,350				
Town of Batavia 1/	5,440	8,460	11,550				
Wyoming County 4/	37,688	42,021	46,500	49,533	52,566	55,600	56,000*
Buffalo SMSA	1,350,597	1,319,400	1,370,200	1,419,600	1,470,450 2/	1,521,300	1,597,600 3/
Rochester SMSA	883,574	1,059,000	1,247,000	1,412,500	1,558,200 2/	1,703,900	1,840,212 3/

* Data extended to 2030 based upon historical trend and planned extensions of municipal services into portions of the country.

1/ Data developed by Batavia Area Planning Board
2/ Interpolated value
3/ Estimated value based on observed historical trend
4/ Data for 1980 based on NYSOPS revised data; 1990 and 2020 data based on County Comprehensive Sewerage Study - 1970 (Teetor-Dobbins Consulting Engineers, Rochester, NY); other points represent interpolated or extrapolated values.

Table B6 - Projections of Population and Employment for Selected Areas

	Actual	Projected					
	1970	1980	1990	2000	2010 1/	2020	2030 2/
Population in Buffalo SMSA	1,350,597	1,319,400	1,370,200	1,419,600	1,470,450	1,521,300	1,597,600
Employment/Population Ratio	.38	.42	.45	.45	.45	.45	.45
Estimated Employment	515,261	554,148	589,190	638,820	661,700	684,585	718,920
Population in Genesee County	58,722	64,464	70,935	75,709	78,000	82,000	85,000
Employment/Population Ratio	.38	.41	.42	.44	.44	.44	.44
Estimated Employment	22,548	26,430	29,790	33,310	34,320	36,080	37,400
Population in Wyoming County	37,688	42,021	46,500	49,500	52,600	55,600	56,000
Employment/Population Ratio	.36	.37	.38	.39	.40	.41	.42
Estimated Employment	13,422	15,500	17,600	19,300	21,000	22,800	23,500

1/ Interpolated value
2/ Estimated value based on historical trend

Source: OBERS, Series E-1972, Volumes 4, 5, 7, U.S. Water Resources Council

counties which comprise this subarea are rural in nature and more accurately reflects Genesee County's emphasis upon agricultural activity. Employment-population ratios were slightly lower in Subarea 0413 than in either SMSA which borders on the watershed. Table B6 contains estimates of future employment levels. Very little employment growth is projected for Wyoming County since future population growth expected to occur in the western portion of this county contiguous to Erie County will find employment within the Buffalo metropolitan area.

(2) Genesee and Wyoming Counties

B2.13 Manufacturing employment in the upper portions of the watershed is concentrated primarily within the city of Batavia. Table B7 presents the relative concentration of industrial employment for all of Genesee County's largest population centers.

B2.14 Most of the larger industrial employers within Genesee County are located in the city of Batavia and account for almost 30 percent of total manufacturing employment within the county. The evolution of Batavia as an industrial center has been based upon several factors; it was the first area settled, it is older than any of the cities and villages which surround it and has long been designated as the county seat. Its geographic location and proximity to extensive interregional rail networks have also contributed to the growth in Batavia's manufacturing sector. As the settlement of this area proceeded, the city became the commercial and manufacturing center which served the surrounding agricultural hinterland. Batavia's central location between two of New York State's largest market centers (Buffalo and Rochester) has attracted many large industrial employers to this location.

Table B7 - Distribution of Manufacturing Employment in Genesee County (1970)

Area	Employment		Manufacturing as Percent of County Industrial Employment
	Total	Manufacturing	%
Genesee County	22,548	8,160	100
City of Batavia	7,016	2,410	30
Town of Batavia	2,144	610	7
Town of Leroy	3,123	1,450	18
Village of Leroy	2,025	950	12
Town of Pembroke	1,518	500	6
Town of Oakfield	2,025	950	12

SOURCE: Business Fact Book - Rochester Area, New York State Department of Commerce

B2.15 Genesee County outweight Wyoming County in terms of total industrial employment, number of manufacturing units and value added by manufacturers. Value added is considered to be the best economic measure now available for comparing the relative importance of manufacturing among

industries and geographic areas. Detailed statistics for both counties are contained in Table B8.

Table B8 - Manufacturing Employment Value Added and Employment Statistics for Selected Counties

Area	1972 Total Establishments	1972 Total Employment	1972 Value Added $ Millions	1967 Total Employees	1967 Value Added $ Millions
Genesee County	93	6,800	90.6	7,600	97.1
City of Batavia	50	4,000	38.7	4,700	51.2
Village of LeRoy	14	1,900	37.6	1,800	29.8
Wyoming County	48	3,900	50.0	3,400	41.8
Warsaw	6	D	D	D	D
Perry	7	600	7.9	1,000	6.0

D - Data withheld to avoid disclosure of individual companies.

SOURCE: 1972 Census of Manufacturers, U. S. Department of Commerce, Bureau of the Census.

B2.16 The 1972 Census of Manufacturers was also used to determine the relative importance of manufacturing activity by Standard Industrial Classification (SIC) Code. Genesee County's largest concentration of industrial employment was in stone, clay and glass operations whereas manufacturing employment in Wyoming County was centered in the production of electrical and electronic equipment. Value added by SIC category is presented in Table B9.

B2.17 The successful development of the Batavia Industrial Park has also contributed to the viability of industrial activity within this city. Adequate utilities are supplied to this area by Niagara Mohawk Corporation (electric) and National Fuel Gas (natural gas). The water supply for this area originates from wells and Tonawanda Creek and an existing expansion program will eventually double the filtration plant and storage capacity from 3 MGD to 6 MGD. Water supply is not considered to be a constraint on industrial activity in this area.

B2.18 Existence of a Genesee Industrial Development Corporation and the New York State Job Development Authority has also contributed to growth in industrial activity. The Industrial Development Corporation is a nonprofit corporation established to assist and promote the development of industry in Genesee County whereas the Job Development Authority guarantees second mortgage loans for industrial building through local development corporations.

Table B9 - Industrial Statistics for Selected Industry Groups in Genesee and Wyoming Counties, 1972

SIC Code	Code	Total Establishments	Employees	Value Added $ Millions	Employees	Value Added $ Millions
	Genesee County	93	6,800	90.6	7,600	97.1
20	Food & kindred products	13	600	9.7	700	9.8
32	Stone, clay and glass	9	1,400	26.9	(NA)	(NA)
34	Fabricated metals	11	600	13.0	(NA)	(NA)
35	Machinery, exc elect.	15	800	14.9	900	13.2
	Wyoming County	48	3,900	50.0	3,400	41.8
36	Electric, electronic equipment	5	2,100	26.4	(NA)	(NA)

SOURCE: 1972 Census of Manufacturers, U. S. Department of Commerce, Bureau of the Census.

B2.19 Future projections of manufacturing employment have considered the role Batavia has historically played in Genesee County. Completion of the Urban Renewal Project in Batavia's Central Business District (CBD) has accelerated the growth in tertiary employment. A half dozen new buildings have already been built in the CBD due to this renewal project while others are now under construction or planned.

B2.20 In light of this stimulus to commercial employment levels the relative importance of manufacturing employment is anticipated to decline slightly in the foreseeable future. Table B10 presents the estimated levels of manufacturing employment in both Genesee and Wyoming Counties.

(3) Commercial Employment

B2.21 The total value of retail sales increase[illegible] almost [illegible]2 percent in the Buffalo SMSA, slightly above the increase posted at the State level for the period 1963 to 1967, Table B11. The proportion of retail trade sales recorded outside the city of Buffalo increased during this period. In 1963 almost 42 percent of the total value of retail sales occurred within Buffalo but by 1967 this had declined to 39 percent. Rapidly growing suburbs around the cities of Buffalo and Niagara Falls have become increasingly important in recent years. In the SMSA, that portion outside the city of Buffalo accounted for over 61 percent of retail activity, compared with less than 50 percent in 1963.

Table B10 - Historical and Projected Manufacturing Employment in Genesee and Wyoming Counties

Area	Actual	Projected						Total
	1970	1980	1990	2000	2010	2020	2030	Increase
Genesee County								
Total Employment	22,548	26,430	29,790	33,310	34,320	36,000	37,400	10,970
Manufacturing Employment	8,160	9,410	10,486	11,590	11,810	12,265	12,565	3,155
Percent Manufacturing	36.2%	35.6%	35.2%	34.8%	34.4%	34.0%	33.6%	
Wyoming County								
Total Employment	13,422	15,500	17,600	19,300	21,000	22,800	23,500	8,000
Manufacturing Employment	4,310	4,880	5,440	5,850	6,240	6,635	6,700	1,820
Percent Manufacturing	32.1%	31.5%	30.9%	30.3%	29.7%	29.1%	28.5%	

Source: Rochester Area Business Fact Book, New York State Department of Commerce

Table B11 - Retail Trade Statistics
Change in Retail Trade for Selected Areas

	Sales in Thousands			Number of	Total Retail	Employment per
	1963	1967	Percent Increase	Establishments 1967	Employment 1967	Establishment 1967
New York State	23,977,310	29,091,471	21.3	162,194	877,835	5.4
Buffalo SMSA	1,675,205	2,048,828	22.3	11,330	67,739	6.0
Erie County	1,402,688	1,717,947	22.5	9,249	57,246	6.2
Niagara County	272,517	330,881	21.4	2,081	10,493	5.0
Genesee County	80,262	96,717	20.5	551	2,431	4.4
City of Batavia	46,888	59,583	27.0	277	1,625	5.8
Wyoming County	41,138	45,880	11.5	384	1,083	2.8
Village of Attica 1/	4,570	5,652	24.0	42	126	3.0

1/ Wyoming County portion

Source: Buffalo and Rochester Business Fact Books, Part II, NYS Department of Commerce, 1974.

Table B12 - Commercial Employment
(Historical Commercial Employment in the Buffalo SMSA)

Year	Total Nonagricultural Employment	Commercial Employment 1/	Ratio of Commercial Employment to Total Nonagricultural Employment	Percent Wholesale	Percent Retail	Ratio of Retail to Wholesale Trade
	Thousands					
1958	423.3	86.6	.200	NA	NA	NA
1959	435.8	85.5	.196	NA	NA	NA
1960	441.7	84.5	.191	NA	NA	NA
1961	423.0	82.2	.194	NA	NA	NA
1962	426.7	83.3	.195	NA	NA	NA
1963	428.4	84.5	.197	NA	NA	NA
1964	437.3	86.2	.197	NA	NA	NA
1965	455.5	88.7	.198	NA	NA	NA
1966	474.4	92.2	.194	NA	NA	NA
1967	483.6	95.4	.197	24%	76%	3.22
1968	493.6	98.9	.200	24%	76%	3.24
1969	503.6	101.6	.202	23%	77%	3.32
1970	496.9	102.2	.206	23%	77%	3.33

1/ Total commercial employment equals sum of wholesale and retail trade

NA Data not available for calculations required

Source: Employment and Earnings, U.S. Department of Labor.

B2.21 The total value of retail sales increased almost 22 percent in the Buffalo SMSA, slightly above the increase posted at the State level for the period 1963 to 1967, Table B11. The proportion of retail trade sales recorded outside the city of Buffalo increased during this period. In 1963 almost 42 percent of the total value of retail sales occurred within Buffalo but by 1967 this had declined to 39 percent. Rapidly growing suburbs around the cities of Buffalo and Niagara Falls have become increasingly important in recent years. In the SMSA, that portion outside the city of Buffalo accounted for over 61 percent of retail activity, compared with less than 50 percent in 1963.

B2.22 Historically, commercial employment has varied between 19.1 percent and 20.6 percent of total nonagricultural SMSA employment, Table B12. The ratio of commercial to total nonagricultural employment observed in the past was used to project future commercial employment levels within the Buffalo SMSA, Table B13.

Table B13 - Future Commercial Employment - Buffalo SMSA

	Actual	Projected					
	1970	1980	1990	2000	2010	2020	2030
Estimated employment	513,227	554,150	589,190	638,820	661,700	684,585	718,920
Historical commercial employment factor	.199	.199	.199	.199	.199	.199	.199
Commercial employment	102,132	110,275	117,250	127,125	131,680	136,230	143,025

B2.23 Commercial activity within Genesee County is heavily concentrated in the city of Batavia. Between 1963 and 1967 the city increased its share of total county retail transactions from 58 percent to 62 percent. More than one-half of all the county's retail operators are located within the city and employ more than two-thirds of all workers within the commercial sector. Batavia's CBD is the major commercial center not only in Genesee County but in the entire corridor between Rochester and Buffalo.

B2.24 The commercial sector in Wyoming County is less concentrated although 58 percent of total retail sales were recorded in the villages of Warsaw, Perry, and Attica. Wyoming County also recorded the smallest rate of increase in retail sales of any of the four counties that lie in the watershed.

B2.25 The methodology for estimating future commercial employment in the rural upstream area of the watershed is slightly different than that used for Erie or Niagara Counties. Commercial employment as a percentage of total employment in 1970 was used as a guide for estimating future levels of commercial employment. This percentage was assumed to trend slightly upward over the planning period. Greater increases in this proportion can be expected for Genesee County than in Wyoming County. Detailed estimates by decade are included in Table B14.

Table B14 - Future Commercial Employment
Genesee and Wyoming Counties

	Actual: 1970	Projected 1980	1990	2000	2010	2020	2030
Genesee County							
Total employment	22,548	26,430	29,790	33,310	34,320	36,080	37,400
Commercial employment as percent of total	17%	18%	19%	20%	21%	22%	23%
Commercial employment	3,830	4,490	5,060	5,660	5,830	6,130	6,355
Wyoming County							
Total employment	13,422	15,500	17,600	19,300	21,000	22,800	23,500
Commercial employment as percent of total	15%	15.5%	16.0%	16.5%	17.0%	17.5%	18.%
Commercial employment	2,010	2,400	2,800	3,180	3,570	3,990	4,230

(4) Manufacturing Employment

B2.26 Manufacturing employment is the largest sector of employment in the Buffalo SMSA as a whole, as well as in each individual county. Manufacturing activity has historically been enhanced by an adequate supply of hydroelectric power available in western New York. More than one-third of this region's labor force was employed in manufacturing in 1970. Niagara County's labor force is more heavily oriented towards industrial activity than the workforce in Erie County (43 vs 32 percent of total employment in 1970). This higher percentage is attributed to a relatively high ratio of nondurable goods production centering around the manufacture of chemicals in Niagara Falls, NY.

B2.27 Recent developments within the industrial sector of the Buffalo SMSA must be considered before projections of manufacturing employment can be reliably derived for the Buffalo and Niagara Falls metropolitan areas. A slight decrease in manufacturing employment was recorded at the State level between 1950 and 1970, Figure B1. During this interval, manufacturing employment ranged between a high of 2,118,900 in 1953 and a low of 1,769,300 in 1970. The net decline in manufacturing employment was almost eight percent for the twenty-three year period.

B2.28 On the other hand, the Buffalo SMSA experienced a slightly greater drop in manufacturing employment of 10 percent, Figure B2. Since 1970 average annual employment in the SMSA has dropped to a record low of 155,600 in 1974 while the unemployment rate has risen to record levels in both the State and the Buffalo region. Table B15 further illustrates the dwindling industrial employment base of the Buffalo SMSA. In light of the recent downturn in the local economy and the growing importance of trade,

commercial and marketing activities, future levels of manufacturing employment were held constant at the 1970 level of 171,400. This is well above current employment and would provide for any short-term expansion in SMSA industrial employment and, at the same time, accurately reflect the eroding long-term manufacturing outlook for the Buffalo Metropolitan Area.

Table B15 - Industrial Employment - Buffalo SMSA

Year	Number of Manufacturing Establishments	Number of Employees
1958	1,820	173,874
1963	1,808	162,900
1966	1,681	180,600
1969	1,638	178,300
1973	1,570	159,300

SOURCES: County Business Patterns, U. S. Department of Commerce; New York State Department of Labor, Division of Research & Statistics

B2.29 Manufacturing employment, as a percentage of total SMSA employment, is expected to decline significantly from its 1970 value of 33.4 percent. Rapid growth in the commercial sector and service industries will result in a declining proportion of total SMSA employment involved with industrial activity in the future. Table B16 presents the rapidly declining proportion of industrial employment relative to total SMSA employment. Recent evidence of the predicted long-term decline in the relative importance of the manufacturing sector in this area was evident in employment statistics for 1973 and 1974, Table B17.

Table B16 - Estimated Manufacturing Employment - Buffalo SMSA

	Actual:	Projected					
	1970	1980	1990	2000	2010	2020	2030
Estimated Employment	513,230	554,150	589,190	638,820	661,700	684,585	718,920
Manufacturing Employment	171,420	171,420	171,420	171,420	171,420	171,420	171,420
Estimated Manufacturing/Employment Ratio	.334	.309	.291	.268	.259	.250	.238

SOURCE: OBERS, Series E 1972, U. S. Water Resources Council

Table B17 - Current Employment in the Buffalo Labor Area
(in thousands)

Industry	1973	1974
Contract Construction	19.9	18.3
Wholesale & Retail Trade	107.5	108.1
Transportation, public utilities	30.8	29.0
Finance, insurance, real estate	20.1	20.2
Services, mining, miscellaneous	83.6	84.9
Government	80.4	82.3
Manufacturing	159.3	155.6
Total	501.6	498.4
Manufacturing Employment as Percent of Total Employment	32%	31%

c. Agricultural Earnings and Output.

B2.30 Agricultural earnings for all counties within the watershed were projected based upon the predicted increase by OBERS, Projections of Regional Economic Activity in the United States. Actual earnings by all farms in 1969 within Erie and Niagara Counties were projected to grow at the SMSA rate while agricultural revenues projected for the upstream reaches utilize a slightly smaller rate. This smaller growth rate of agricultural earnings was based upon projections for Subarea 0413 which contains Genesee, Wyoming and five other counties situated between Buffalo and Rochester. This area is outside the Buffalo SMSA and was considered to be a more accurate representation of a rural area less exposed to growth pressures originating within a large SMSA. Refer to Table B18 for detailed estimates of agricultural earnings by decade.

B2.31 Agricultural activity within the watershed contributes substantially to the local economy. Dairy farming is the largest single producer of agricultural revenue in each county. While the number of dairy farms have declined steadily for a number of years, herds have become larger and many individual farms have taken on the character of modest sized industries in themselves. With the emergence of large dairy farms has come the increased dependence upon high degrees of mechanization and technical knowledge. It is the continued reliance on this technology upon which projections of future agricultural earnings are based.

B2.32 Agricultural output of each county in the watershed is substantial. The most recent year for which agricultural data is available (1969)

Table B18 - Agricultural Earnings
Projected Agricultural Earnings to 2030
(In Thousands)

	Actual 3/	Projected						Increase in Agricultural Earnings	Percent Increase from 1980 to 2020
	1969	1980	1990	2000	2010 1/	2020	2030 2/		
	$	$	$	$	$	$	$	$	
Erie County	28,016	37,820	39,500	43,425	49,028	54,630	60,235	22,415	59%
Niagara County	15,988	21,583	22,540	24,780	27,980	31,175	34,374	12,791	59%
Genesee County	19,692	22,645	24,420	26,980	30,325	33,870	37,610	14,965	66%
Wyoming County	26,532	30,510	32,890	36,350	40,860	45,635	50,676	20,166	66%

1/ Interpolated value
2/ Estimated value
3/ 1969 earnings based upon 1969 Census of Agriculture, material compiled by New York State Department of Agriculture and Markets.

ranks Erie County as the number one producer within the watershed in terms of value of agricultural output. Erie County's agricultural output exceeded $28.0 million in 1969; Wyoming County followed closely behind with $26.5 million. Details concerning the value of agricultural output for the other two counties are included in Table B19.

B2.33 Principal agricultural commodities within the watershed include dairy products, field crops, vegetables, fruits and nuts, and livestock other than poultry. In the lower portion of the watershed (Erie and Niagara Counties) there is a stronger emphasis upon those commodities usually associated with truck farm operations which serve urban centers. Genesee and Wyoming Counties are strongly oriented towards dairy farming and the production of those field crops required to support dairy animals.

B2.34 A greater percentage of farms in the upper reaches of the watershed are commercial farms which produce at least $2,500 or more per year of agricultural commodities. Niagara County has the highest proportion of farms which produce less than $2,500 of output per year, Table B20. In contrast, the highest proportion of farms earnings at least $2,500 per year are located in Wyoming County. This increased commercial farm activity may be partly attributed to the elimination of inefficient farm operations and the decline in the number of part-time farm operators. Those farms near the Buffalo SMSA are more likely to be operated on a part-time or seasonal basis, whereas farms located farther upstream provide the principal sources of income for their owner-operators and tend to be larger in size with greater capital investment required.

d. Per Capita Income.

B2.35 Average per capita income in New York State has historically exceeded the per capita income in the Buffalo SMSA. This trend is expected to continue into the future based upon Series E data, Table B21. The per capita income of the Rochester SMSA is also below the State average but above that of the Buffalo SMSA. In 1969, the Rochester area's median family income was $11,539, the highest of all Upstate economic areas, $1,323 greater than that for Upstate as a whole and $922 higher than the State's median. Rochester's relative affluence can be primarily attributed to Monroe County's median family income which was fourth highest among all the State's counties. High incomes in this area are in turn attributed to Rochester's reputation for high quality, precision manufacturing products and the existence of the type of labor force required to produce these types of products.

B2.36 Skilled workers - craftsmen and foremen - comprise almost 15 percent of the area's working residents, the second highest proportion among all the economic areas. This area is also characterized by a better-than-average representation of people in professional and technical positions due to the extensive research activities of such firms as Eastman Kodak, Xerox Corporation, and Bausch and Lomb, Inc.

Table B19 - Agricultural Output
Value of Products Sold by County
(Thousands of Dollars)

County	Value of Products Sold in 1969								
	Total	Dairy Products	Poultry & Prdts	Other Livestock	Field Crops	Vegetables	Fruits & Nuts	Nursery & Greenhouse	Forest Products
Erie County	28,016	12,456	2,682	2,845	1,187	3,980	1,397	3,407	62
Percent of total		44	10	10	4	14	5	12	*
Niagara County	15,988	4,774	702	2,023	1,438	1,097	4,910	1,025	18
Percent of total		30	4	13	9	9	31	6	*
Genesee County	19,692	9,719	1,163	2,101	3,037	2,983	39	605	44
Percent of total		49	6	11	15	15	*	3	*
Wyoming County	26,532	18,587	598	3,263	3,644	108	(D)	(D)	165
Percent of total		70	2	12	14	*	(D)	(D)	1

* Less than one percent

D - Data withheld to avoid disclosure of information for individual farm

Source: 1969 Census of Agriculture, U.S. Bureau of the Census, material compiled by New York State Department of Agriculture and Markets.

Table B20 - Agricultural Activity
Number of Farms, Acreage, and Value
of Land and Buildings - 1969

County	Number of Farms			Acres in Farms		Average Value of Land & Bldg. per acre
	Total	Class 1-5 1/	All Others 2/	Percent of Total Area	Average Acres Per Farm	$
Erie County	1,680	983	697	33%	132	54,492
Niagara County	1,654	731	923	50%	104	39,667
Genesee County	1,029	618	411	61%	191	52,479
Wyoming County	1,140	826	314	63%	210	46,143
New York State	51,909	34,404	17,505	33%	196	53,399

1/ Farms for which sales of farm products amounted to at least $2,500 or more per year.
2/ Total of all farms minus Classes 1-5 constitutes all others

Source: 1969 Census of Agriculture, U.S. Bureau of Census, material compiled by New York State Department of Agriculture and Markets.

Table B21 - Per Capita Income
(Historical and Projected Per Capita Income Levels)
(1967 dollars)

	1950	1960 1/	1970	1980	1990	2000	2010 2/	2020	2030 3/
Buffalo SMSA	2,436	2,613	3,569	4,900	6,300	8,400	11,050	13,700	15,944
Rochester SMSA	2,372	2,905	3,940	5,400	7,000	9,100	11,800	14,500	16,500
Non-SMSA Portions of water resource subareas	1,833	2,180	3,199	4,400	5,800	7,800	10,350	12,900	13,900
New York State	2,619	3,135	4,252	5,700	7,300	9,500	12,150	14,800	16,720
United States	2,064	2,770	3,476	4,700	6,100	8,100	10,650	13,200	15,324

1/ Interpolated from 1962 value
2/ Interpolated from actual values available for years 2000 and 2020
3/ Estimated based upon historical trends

Source: OBERS Series E, 1972 Volumes 4, 5, 7, U.S. Water Resources Council.

B3. PROJECTED LAND USE DEMAND IN THE AFFECTED AREA

B3.1 Future estimates of various land use demands presented in this section are based upon the most recent economic and demographic information available for this area. These figures approximate future land demands which may not actually occur in the affected area due to a major change in the economic health of the Buffalo Metropolitan Area or its hinterland.

a. Residential Demand.

(1) Buffalo Standard Metropolitan Area

B3.2 Residential land use demand was obtained by converting population projections within the affected area to acres. Population increases by decade were converted into household equivalents by use of a factor for average number of occupants per household. This number was assumed to decline in the foreseeable future, a trend substantiated by research conducted by the Bureau of Census which established that the number of persons living in the average American household declined from 3.19 to 2.97 between 1969 and 1974.

B3.3 Increases in households in the SMSA were distributed between single family and multi-family housing units. In 1970, 62.9 percent of all housing units were owner-occupied in the SMSA. The number of new single family units to be constructed in the SMSA is expected to be significantly smaller than the number of existing single family units. A range of residential densities was applied to the distribution ot households to derive net residential land use demand for the SMSA by decade.

B3.4 This method of analysis was applied to other population projections to determine their sensitivity on total residential land demand. Residential land demand based on OBERS data did not vary significantly from those determined from other statistical series. Land required for single family units in the SMSA is expected to vary from a low of 4,360 acres to a high of 6,100 acres. Land required for multi-family land demand is expected to vary from a low of 3,370 to a high of 5,640 acres. The total residential land demand in the SMSA, depending upon the various combinations of single or multi-family developments will fall between 7,730 and 11,732 acres. Land demand, viewed as a range of possible values, accurately reflects the potential fluctuation in variables such as employment, population shifts, land costs, building and material costs, and availability of financing which cannot be predicted with accuracy over the 50-year planning period. A summary of residential land demand for the Buffalo SMSA is presented in Table B22.

(2) Genesee and Wyoming Counties

B3.5 Future residential land use demand in Genesee County is anticipated to occur in and around the town of Batavia. Large areas of open space and low densities will continue to characterize the remaining portion of Genesee County within the watershed. Future population growth will become increasingly urban-oriented.

Table B22 - Future Residential Land Use
Demand in the Buffalo SMSA

	1980 to 1990	1990 to 2000	2000 to 2010	2010 to 2020	2020 to 2030	Total
Projected Population Increase 1/	50,800	49,400	50,850	50,850	76,300	
Projected Household Size	2.90	2.85	2.80	2.75	2.70	
Estimated Increase in Households	17,520	17,300	18,160	18,490	28,260	
Singl´ Family Distribution Factor	.25	.20	.15	.10	.10	
Increase in Single Family Units	4,380	3,460	2,724	1,849	2,826	
Projected Residential Density (Units per Acre)						
2.5	1,752	1,384	1,090	740	1,130	6,096
3.0	1,460	1,150	908	620	942	5,080
3.5	1,250	990	780	530	810	4,360
Multi-Family Distribution Factor	.75	.80	.85	.90	.90	
Increase in Multi-Family Units	13,140	13,840	15,436	16,641	25,434	
Projected Residential Density (Units per Acre)						
15	876	920	1,030	1,110	1,700	5,636
20	660	690	770	830	1,270	4,220
25	520	550	620	660	1,020	3,370

1/ 1972 Series E-OBERS, Population Projections, Vol. V, U.S. Water Resources Council.

B3.6 The city and town of Batavia contains a total of about 35,200 acres, or slightly less than 55 square miles. Approximately ten percent (3,667 acres) of the total acreage in the town of Batavia area lies within the city. Of the combined land area in the two communities only 14 percent, or 5,084 acres, was developed as of 1967. The remaining area, 30,110 acres, was vacant or in nonurban uses such as woodlands or agricultural lands.

B3.7 Future growth in the Batavia area will be influenced by local conditions, as well as external forces originating from the two large SMSA's to the east and west. The existence of large tracts of open land outside the city is expected to provide the necessary area required to house future increases in the area's population.

B3.8 Minimal residential growth is expected to occur in Wyoming County. Most of the future residential development should occur in those communities located outside and west of the watershed as a result of developmental pressures originating within the city of Buffalo. Communities such as Attica, Orangeville, and the towns of North Java and Wethersfield are expected to maintain a steady-state condition. This stability in population will produce only a modest residential land use demand.

B3.9 A methodology similar to that used in projecting residential land use demand in the Buffalo SMSA was used to estimate future residential land use demand in Genesee and Wyoming Counties. Land required for new residential use during the 50-year planning period should fall in the range of 1,280 to 2,200 acres for Genesee County and between 600 and 1,100 acres for Wyoming County. A range of values was considered appropriate since the inputs into residential land use demand are numerous and, for the most part, uncertain in the short run.

b. Commercial Use Demand.

(1) Buffalo Standard Metropolitan Area

B3.10 Historical employment per establishment has been utilized to estimate commercial land use demand within the Buffalo SMSA. Projected commercial employment, in conjunction with an assumed range of site sizes and a distribution of future commercial employment between the retail and wholesale sectors, was used to derive future commercial land use demand. Data on average employment per commercial establishment was presented in Table B6. Future employment per establishment is expected to increase slightly from the 1970 benchmark for both the retail and wholesale sectors. Site sizes were assumed to vary from .75 to 1.00 acres per future retail unit and from 2.0 to 4.0 acres per wholesale unit.

B3.11 Aggregate commercial land use demand in the Buffalo SMSA ranges from a low of 4,900 acres to a high of 7,500 acres based upon expected population and employment. Although a net land use demand exists for the commercial sector between 1980 and 2030, specific localities within the Buffalo SMSA may have negative or positive commercial land use requirements. Table B23 contains incremental commercial land use demand by decade.

Table B23 - Commercial Land Use Demand
in the Buffalo SMSA

	1980 to 1990	1990 to 2000	2000 to 2010	2010 to 2020	2020 to 2030	Total
Increase in Commercial Employment	6,975	9,875	4,555	4,550	6,795	32,750
Retail - 75 Percent 1/	5,230	7,400	3,415	3,410	5,095	24,550
Employment per Establishment	5.5	5.3	5.1	4.9	4.7	
Increase in Future Retail Establishment	950	1,395	670	695	1,085	
.75 acre per site	712	1,045	500	520	810	3,587
1.00 acre per site	950	1,395	670	695	1,085	4,795
Wholesale - 25 Percent 1/	1,745	2,475	1,140	1,140	1,700	
Employment per Establishment	12.5	12.0	11.75	11.50	11.25	
Wholesale Establishments	140	150	97	100	150	
2.0 acres per site	280	400	190	200	300	1,386
4.0 acres per site	560	824	388	400	600	2,772

1/ Distribution between retail and wholesale sectors was derived from Table B6 and trends during the period 1967-1970.

(2) Genesee and Wyoming Counties

B3.12 Commercial land use demand in Genesee and Wyoming Counties was estimated using a similar methodology. In general, commercial establishments in Wyoming County were smaller in terms of average employment per retail unit, Table B6. In addition, per capita retail sales was substantially less than its counterparts in Genesee County ($1,335 vs $1,719). Retail units in Wyoming County also averaged less total sales value than similar units located in Genesee County ($119,500 vs $175,500). Any differences between these two adjoining counties in terms of retail sales is most likely attributable to the closer proximity of Genesee County to economic activity in the Rochester and Buffalo SMSA's. Wyoming County is also well removed from the influence of Monroe County (with retail sales per capita of $1,840) which accounted for more than 80 percent of all retail transactions in and around the Rochester Metropolitan Area. Genesee County also lies within the development corridor between two major metropolitan areas.

B3.13 Land demand over the next 50 years by all commercial units in Wyoming County has been estimated to range from 100 to 170 acres. In contrast, Genesee County's future commercial units should require between 215 and 365 acres of land.

c. Industrial Use Demand.

(1) Buffalo Standard Metropolitan Area

B3.14 All industrial firms located in the downstream reaches of watershed are also within the Buffalo SMSA. Industrial activity in upper reaches is concentrated within the town and city of Batavia.

B3.15 Industrial land use in the SMSA exceeded 14,890 acres in 1967. This represents approximately 1.5 percent of the total land area that lies within the SMSA. At this time, a great deal of those 14,890 acres were located within the two major metropolitan areas of Buffalo and Niagara Falls.

B3.16 Future economic development trends, especially those trends relative to industrial activity within Erie and Niagara Counties, were partially quantified by a survey of private and public employers conducted by the Erie and Niagara Counties Regional Planning Board (ENCRPB). This survey was titled Economic Development in the Erie-Niagara Region and was released in October 1975. Portions of that survey were used to obtain an estimate of future industrial land use demand within the affected area.

B3.17 Growth potential in the Erie-Niagara Region was evaluated by ENCRPB on several points. Firms in the area were questioned for information on the potential for attracting "supplier" firms to the area. Results indicate that over 80 percent of the companies in the SMSA purchase substantial amounts of semi-finished goods, parts, supplies, and/or raw materials from outside of the SMSA. While nonavailability of these items locally is the principal reason for these outside purchases, other respondents indicated that local firms could not sell these items at competitive prices.

B3.18 The survey also disclosed that trade with Canada is generally at a low level and the majority of firms did not anticipate any improvement. Duties and other trade regulations were given as the major inhibiting factors to expansion of business with Canada.

B3.19 A very small proportion of all firms surveyed (3.6 percent) have moved into the area within the last 10 years. Industrial firms entering the area have generally located in the outlying areas of both counties. Availability of materials and market potential were the major attractions most often cited by firms who moved into the Buffalo SMSA. Slightly more than 40 percent of industrial firms responding to the survey have expanded their plants over the last three years. The largest additions (in square feet) were located in the city of Buffalo. Expansion plans for 1975 reflected the recent downturn in the economy and were fewer than the annual average of the previous three years.

B3.20 The majority of firms surveyed indicated that they have sufficient space to expand at their present sites. Firms who did not have additional room for expansion stated that they would be willing to build additional facilities somewhere within the two-county area, while others specifically stated a preference for a location within an industrial park located in the SMSA.

B3.21 Substantial capital investment by the manufacturing sector has occurred in the Erie-Niagara area. Within the industrial group, the proportion of firms investing in new equipment during the past few years was highest in the outlying areas of both counties. However, the dollar value of investment in plant and equipment was greatest in the cities of Buffalo and Niagara Falls, NY.

B3.22 The economic health of existing industries will be very important in determining the extent of future industrial land use demand in the area. Gains in employment within the manufacturing sector were used as indicators of the extent of growth which might be anticipated by manufacturing firms over the planning period. Manufacturing employment in the SMSA was assumed to remain constant at its 1970 level of 171,400. This stability in employment does not reflect the expected net growth in nondurable and durable goods components. Manufacturing employment in Erie County is anticipated to decline moderately during the planning period whereas very little change is expected in Niagara County. This is primarily attributed to a much higher proportion of workers in the durable goods sector in Erie County. An anticipated decline in employment in the durable goods sector in Erie County will not offset the slight gain predicted in nondurable goods manufacturing. In Niagara County any drop in employment in the nondurable goods sector will be offset by gains in durable goods employment. This has been the historical pattern and is expected to continue.

B3.23 Therefore, it was estimated that Niagara County would have a net increase in industrial employment while Erie County would have a moderate decline resulting in minimal net land use demand within the SMSA. However, within Niagara County a net demand for industrial land use would exist due to gains in the nondurable goods sector.

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B3.24 The most significant factor complicating the analysis of industrial land use demand is the lack of information concerning the total number of acres currently held in reserve by the industrial sector. Also, the inability to determine when the available supply of land for expansion at present sites will be exhausted prevents a detailed quantification of net industrial land demand.

B3.25 Land use demand during the planning period will be exerted primarily by two groups: firms who do not have land available for expansion and new firms entering the region. The extent of undeveloped acreage now in industrial parks will greatly dampen net industrial land use demand within the Buffalo SMSA.

B3.26 New firms entering the area have the greatest need for land and construction of new facilities (historically, new growth has located outside the city of Buffalo). Very few firms have moved into the city in the last 10 years to increase the existing industrial base.

B3.27 Approximately 1,700 acres lie within established industrial parks in and around the Buffalo Metropolitan Area. It is estimated that less than one-half (850 acres) of this amount is currently developed. Additional industrial park sites are also available near the city of Niagara Falls although detailed information was not obtained for them. Assuming that industrial land use demand in this area is equivalent to the national absorption rate for land use in industrial parks (15 acres per year) there is sufficient land currently available for at least another 50 years of industrial growth in this area. This time frame is considered reasonable in light of recent developments in the local economy and decline in this area's industrial employment.

(2) Genesee and Wyoming Counties

B3.28 The availability of a sizable labor force, growing population, adequate supply of land, central location between Buffalo and Rochester, plus access to regional transportation networks is expected to bring additional industrial employment into the Batavia area.

B3.29 Historically, industrial firms have been attracted to that portion of the city of Batavia south of Route 5 where large tracts of land adjacent to railroad mainlines and railroad sidings has been available. This historical dependence by industry upon access to railroads is expected to diminish in the future.

B3.30 The major concentration of general industrial development within the Batavia area is planned along the southern boundary of the city extending into the town. Sites designated for general industrial use encompass an area of 1,500 acres. Subtracting the existing railroad rights-of-way and the gravel mines (total of 850 acres) future industrial growth has been allocated 650 acres. An additional 800 acres located north of Thruway Exit 48 has also been designated by local planners for industrial growth. The third category of planned industrial development in the town of Batavia occupies an area of approximately 330 acres and has been designated for future research and development uses.

B3.31 Manufacturing employment is projected to increase by 3,100 over the planning period. To prepare for this growth town planners have already allocated 1,700 acres of land within the city and town for industrial use. This acreage exceeds actual requirements for the projected growth in this county's manufacturing labor force. Although a small fraction of this proposed industrial acreage lies within the 100-year flood plain, the principle of economic rationality is assumed to prevail with the vacant acreage outside the 100-year flood plain developing first.

d. Agricultural Use Demand.

B3.32 Recent increases in agricultural earnings are in sharp contrast to the projected decline in the future estimates of cropland and total acreage in farms. Projected agricultural acreages in New York State are included in Table B24. Between 1980 and 2020 total cropland harvested is expected to decline at a faster rate (down 30 percent) than total land in farms (down 18 percent).

B3.33 The long-term trend towards consolidation of many smaller farms into fewer, but larger, agricultural units is expected to continue in New York State. Consolidation of agricultural activity is also expected to occur in the watershed but at a slower rate than in recent decades. Average farm size and production per farm unit will increase over time. Advances in technology have enabled farmers in New York State to increase their physical output over the last 50 years by 30 percent while the number of farms declined to fewer than 25 percent of their original number. Trends in the dairy sector toward higher milk output with fewer animals and fewer farm laborers is primarily attributed to better feeding and breeding techniques and advances in large-scale milk handling systems. Dairy operators are also becoming increasingly dependent upon specialized labor and equipment which is made available by agribusiness enterprises located in the region. Farmers are able to maintain their operations with less on-the-farm labor and increased reliance upon supportive services provided by Contractors.

B3.34 Crop yields per acre will increase significantly due to more intensive farm management techniques. Special climatic and market conditions in the Erie-Ontario Lake Plain should also continue to encourage farmers to produce fruit and vegetables.

Table B24 - Land in Farms Projected
Farmlands in New York State

	Actual			Projected				1980-2020 Percent Change	
	1959	1964	1969	1980	1985	2000	2020	New York	United States
Cropland Harvested 1/	5,032.7	4,742.7	3,835.6	3,687.9	3,612.8	3,011.6	2,500.9	-32%	-13%
Feed Crops 2/	4,230.2	4,048.3	Nc	3,127.5	3,069.1	2,549.8	2,110.4	-33%	Nc
Food Crops 3/	759.4	687.1	Nc	540.4	523.8	443.6	376.0	-30%	Nc
Other Crops 4/	72.8	58.8	Nc	62.9	61.8	53.3	43.5	-31%	Nc
Cropland not Harvested	2,088.0	1,727.3	2,246.2	1,957.7	1,958.6	2,350.3	2,618.8	+34%	+22%
Percentage of Land Cropped	41%	36%	59%	53%	54%	78%	105%		
Total Cropland	7,120.6	6,470.0	6,081.8	5,645.6	5,571.3	5,361.9	5,119.7	-18%	0%
Nonproductive	6,368.9	5,805.4	4,066.5	3,616.5	3,482.2	3,079.1	2,471.2	-32%	-6%
Total Land in Farms	13,489.5	12,275.4	10,148.3	9,053.5	9,053.5	8,441.0	7,590.9	-18%	-4%

1/ sum of feed crops and food crops and other crops may exceed cropland harvested due to double cropping
2/ includes corn, grain sorghum, oats, barley, hay, and silage
3/ includes wheat, rye, rice, citrus and noncitrus fruits, vegetables, sugar cane, sugar beets, Irish potatoes, sweet potatoes, dry beans, and dry peas
4/ includes soybeans, peanuts, flaxseed, cotton, tobacco, and other miscellaneous crops
Nc not calculated

Source: 1972 OBERS Projections of Regional Economic Activity in the U.S. Volume IV, "States," U.S. Water Resources Council, Washington, DC

B4. FLOODING AND PHYSICAL CHARACTERISTICS

B4.1 Characteristics of the major flood plains of the watershed were ascertained in order to determine their potential uses. Those characteristics which make the flood plains attractive or unattractive to potential developers include: flooding characteristics, flood plain characteristics, available services, and existing activities.

a. Flooding Characteristics.

B4.2 The damage caused by any flood depends, in general, on the area flooded, heights of flooding, velocities of flows, rates of rise, durations of flooding, and amount and character of flood plain development. The following section describes the existing flood situation including natural storage, recreation, open space, wildlife, wetlands, and water-oriented transportation in the Tonawanda Creek flood plain.

B4.3 Annual flooding, usually occurring in the late winter or early spring, has caused extensive damage in the Tonawanda Creek Watershed within an 84-mile reach extending from the village of Attica to the mouth of the creek on the Niagara River. Large tracts of primarily agricultural land, particularly in the area below Hopkins Road (mile 41.5) and upstream from the city of Batavia (mile 65.5 to mile 73.5) have been inundated annually. Extensive damage has resulted when floodwaters have overflowed from Tonawanda Creek into the adjacent Mud, Ransom, and Black Creek Watersheds.

B4.4 A detailed damage survey was conducted by the Corps of Engineers during the winter of 1975. The area surveyed extends from the mouth of Tonawanda Creek upstream through the city of Batavia, a distance of about 66 miles. The results of this survey were used as the basis for determining average annual losses from estimated future flooding and benefits attributable to the various plans of improvement under consideration.

(1) Damage from Past Floods

B4.5 Flooding by Tonawanda Creek caused considerable damage during the years 1942, 1956, 1957, 1959, and 1960. Serious flooding was also reported in 1902, 1916, and 1917. In the agricultural reaches damaging floods occur at least once each year. The flood having had the highest discharge at the USGS gage located in the city of Batavia occurred in March 1960. Damages in 1960 were greatly reduced in the city by the Corps of Engineers channel modification project completed in 1955 and by emergency measures taken by the city of Batavia to prevent failure of the existing levee in Kibbe Park. In March 1942, a slightly lesser flood overtopped this levee, resulting in the highest damage experienced to date in the city of Batavia. Table B25 shows estimates of damage which the 1942, 1956, and 1960 floods would now cause in the watershed based on December 1975 price levels and conditions of development.

Table B25 - Estimated Damaged that Recurrences of the 1942, 1956, and 1960 Floods Would Cause Now, December 1975 Prices and Development

Flood Date	Lower Tonawanda Creek		Hopkins Road to Attica	
	Recur. Interval in Years	Estimated Damages 1/	Recur. Interval in Years	Estimated Damages 1/
1942	2	750,000	11	620,000
1956	5	1,600,000	12	1,350,000
1960	10	2,500,000	30	3,140,000

1/ Estimated damages do not include agricultural damages.

(2) Extent of Flooding

B4.6 Flooding has been negligible below the confluence of Tonawanda Creek and the New York State Barge Canal (mile 11.0). Maintenance of minimum channel depths and widths for waterborne barge traffic has provided sufficient capacity for most past floods. From this confluence to a point about two miles upstream of the hamlet of Rapids (mile 20.5) flooding has been generally limited to overflow at channel bends, with the inundated area having a maximum width of about 1,000 feet. From this point to Hopkins Road (mile 41.5) Tonawanda Creek annually inundates vast areas on both sides of its channel. In several areas, floodwaters have flowed across natural divides into the Mud, Ransom, and Black Creek Watersheds. In these areas, the flood plain width is as great as four miles. At mile 22.0 on Tonawanda Creek, floodwaters frequently overtop Salt Road and flow into the Ransom and Black Creek Watersheds. When this occurred in 1960, the Ransom and Black Creek flood plains were approximately 8,000 feet in width from Salt Road downstream to a point just upstream of the confluence of Ransom and Tonawanda Creeks. Overflow from Tonawanda Creek to Mud Creek Watershed has occurred frequently just downstream of Hopkins Road. In 1960 the Mud Creek flood plain varied from 500 feet to 8,000 feet in width from a point just downstream of Hopkins Road to a point north of the hamlet of Rapids. The areas inundated by the March 1960 flood on Tonawanda, Mud, Ransom, and Black Creeks are shown on Plate B3.

B4.7 From Hopkins Road eastward to Bushville, flooding has been minimal. This is attributable to the channels having both high banks and a steep channel bottom slope in this reach. From Bushville eastward to the westerly city limits of Batavia the flood plain has varied from 500 feet to 1,500 feet in width, inundating both Route 5 and South Main Street during the 1960 flood.

B4.8 In the city of Batavia, the areas subject to flooding lie along both banks of the creek. Since completion of the Corps of Engineers channel improvement project in 1955, there have been only minor economic losses reported in the area from just west of the western city limit to the

southerly city limit at the Lehigh Valley Railroad Bridge. The project was designed for a discharge of 6,000 cfs, the discharge of the 1942 flood. The area inundated by the 1960 flood, the flood of record, inundated only 200 acres in the town of Batavia which includes the hamlet of Bushville. Although the discharge for the 1960 flood, 7,200 cfs, exceeded the design capacity of the existing project, emergency measures taken by the city prevented overtopping of the city levee in Kibbe Park.

B4.9 Just upstream of the Lehigh Valley Railroad Bridge, which is located near the southerly limit of the city, the flood plain widens to occupy a large lowland area which extends upstream about 12 miles, to the village of Alexander. Flooding at this area reached a width of 12,000 feet in 1960. The area serves as a natural reservoir which helps reduce the discharges of Tonawanda Creek through the city of Batavia. The area inundated by the March 1960 flood is shown on Plate B4.

B4.10 Within the village of Alexander there is a low, flat area on the right bank nearly 2,000 feet wide which is often flooded. The higher areas on the left bank are seldom flooded. From Alexander to Attica the width of the flood plain varies from 1,000 to 2,000 feet. Within the village of Attica, the flood plain is about 1,000 feet at its widest point, near the upstream village limits. The areas inundated by the March 1960 flood are shown on Plate B5.

(3) Existing Use of the Flood Plains

B4.11 The flood plain of the lower Tonawanda Creek watershed is used primarily by residential and commercial developments with a scattering of public facilities and agricultural activity. Agricultural activities in the flood plains include dairying and the cultivation of cash or field crops such as wheat, corn, oats, alfalfa, hay, etc. There has been a recent trend toward raising winter wheat which can withstand a certain amount of flooding and toward raising corn which can be planted later in the spring, generally when the risk of flooding is lower. A few small orchards are also maintained. Timber, some virgin, and some second growth, includes oak, elm, hickory, maple, black walnut, cedar, and basswood. Frequent overflow and lack of adequate drainage prevents more intensive cultivation in these areas. Flooding for lengthy periods, often running several weeks, saturates the land, delays spring planting and use of pasture, and in some cases restricts production to a single crop where two crops might be possible.

B4.12 The flood plain in the vicinity of Bushville is used mainly for medium-value residences and commercial establishments along Route 5. There are several modern motels, some of which have suffered first-floor flooding and have had to evacuate guests. There is also some farmland in this reach, but agricultural damage is inappreciable and no estimate of these losses was made.

B4.13 The flood plain within the city of Batavia includes residential, commercial, industrial, and public developments. In Reach B1, an area not subject to serious flooding since the Corps project was completed in 1955, most development consists of low- to medium-priced residential units with

some commercial development along West Main Street. Reach B2 is primarily affected by sewer backup. It would be seriously affected again by overland flooding if the city levee in Kibbe Park should fail as it did in March 1942. Development in this reach consists mainly of commercial establishments. Reach B3 is the lowest area in the city of Batavia. The area in the vicinity of Liberty and Sumner Streets is 4 to 5 feet below the level of the Kibbe Park levee. Development in this reach consists of many low- to medium-priced residences, five manufacturering concerns, many commercial establishments along Ellicott Street, three schools, five churches, and other public property. Reaches B4 and B5 consist of low- to medium-value residences. Reach B4 also contains a large undeveloped area. Reach B5 includes two plants of Doehler-Jarvis Corporation, the second largest industry in the city. Although a few homes in Reaches B4 and B5 suffer damage to the first floor furnishings, most damage results from flooded cellars and sewer backup. If the city levee in Kibbe Park should fail as it did in March 1942, water up to 4 or 5 feet deep could flood much of Reaches B3 and B2. State Highways Nos. 5, 33, 63, and 98 pass through the flood plain and traffic occasionally must be rerouted. During periods of minor floods, sections of some streets and many cellars are flooded by reversed flows in the storm and sanitary sewer systems. The sewer system is not adequate to carry high runoff even when the creek is low. Damage may also be caused by reversed flows with negligible local runoff. Reaches B1 through B5 are shown on Plate B4.

B4.14 The area between the city of Batavia and village of Alexander is generally flat and poorly drained. Some of this area is under cultivation, but at a lesser intensity than the lower part of the watershed. Some residential structures are affected by floodwaters.

B4.15 The major component of damage in Alexander is to residential development along Railroad Avenue. The flood plain between the villages of Alexander and Attica is used mostly for agriculture. Development in the village of Attica consists of residential structures on Water, North, and Exchange Streets and a variety of commercial establishments on Water, Main, and Market Streets.

b. Physical Characteristics of the Flood Plain.

(1) Physiography

B4.16 Niagara County borders on Lake Ontario in the Erie-Ontario lowlands, a region of low relief just south of the two Great Lakes. These lowlands are made of lacustrine deposits created beneath glacial lakes; elsewhere there are rolling hills representing ground moraines consisting of irregular masses of boulders, gravel, sand, and clay.

B4.17 The Ontario Lake Plain extends from Lake Ontario south to the Niagara Escarpment. This escarpment has a steep northward slope with bluffs that are exposed in places. Drainage of the Ontario Plain is northward into Lake Ontario. These streams are shallow and meander through narrow flood plains. Between the Ontario Lake Plain on the north and the Cattaraugus Hills on the south, the south Ontario Plain is a rolling area covered with glacial drift. This plain consists of two subplains, the Huron and Erie

plains, separated by the east-west striking Onondaga escarpment. Much of the western portions of these two subplains is within the Buffalo Metropolitan Area.

B4.18 Tonawanda Creek, the border between Erie and Niagara Counties, is centrally located in the Huron Plain and flows westerly to the Niagara River. The Huron Plain is only slightly undulating with flat slopes. This plain slopes westerly from a height of approximately 650 feet near the Onondaga Escarpment in the Tonawanda Indian Reservation to approximately 600 feet in the town of Tonawanda. The eastern boundary of the watershed in the Huron Plain lies near the western limit of Oak Orchard Swamp. Formerly, the Oak Orchard Swamp was a significant source of runoff to the Mud Creek Watershed. This overland flow is now prevented by an extensive dike network recently constructed by New York State.

B4.19 The Erie Plain is bounded by the Onondaga Escarpment, which cuts through the village of Akron along a northeasterly axis, and the Portage Escarpment which extends through the village of Attica in an east-west direction. This subplain is rolling with moderate slopes and, within the watershed, slopes in two directions. Eastern portions of the Erie Plain slope northward while the western portion slopes westward. The remainder of the watershed lies in the Cattaraugus Hills - an area composed of a relatively flattopped upland with deep valleys.

(2) Soils

B4.20 Soil types in the flood plains includes the Genesee, Eel, and Wayland series. These alluvial soils have few limitations for agricultural purposes and are highly rated in terms of productivity. A seasonally high water table, high frequency of flooding, and relatively flat slopes creates local drainage problems that severely limit this area for nonfarm uses.

B4.21 Infrequent flooding occurs between the hamlet of Bushville and the Indian Reservation where Tonawanda Creek enters the Huron Plain. Tonawanda Creek, from its junction with the New York State Barge Canal at Pendleton to the Indian Reservation is a straight line distance of 12 miles but the actual channel distance is 27 miles. Lands on either side of the creek have very flat slopes. The creek has cut a channel averaging 10 to 15 feet deep and roughly 80 feet wide. Tributaries on both sides of the mainstream (Mud, Beeman, Ledge, Murder, and Black Creek) follow shallow, winding, overgrown channels. Divides between the watersheds of these streams are low and poorly defined. During periods of high flow, Tonawanda Creek and some of its tributaries merge and flow across divides in either direction equalizing flood levels. The average area flooded annually is about 10,000 acres. Most of this land is utilized for agriculture or is vacant. With the exception of Ransom Oaks, a planned community that includes single family dwellings, townhouses and apartments capable of housing 1,000 families, there are no large-scale residential subdivisions within the 100-year flood plain.

B4.22 Soil series in the flood plain downstream of the Indian Reservation have severe limitations for nonfarm uses. The Canandaigua-Rhinebeck-Raynham soil association occupies the majority of this area but

Lakemont and Odessa soil series also exist along the southern limits of the flood plain in Erie County. Agricultural productivity of these soils is not as high as that of the soils located in the flood plains of Genesee County but truck and field crops can be grown successfully in many areas. Many low-lying areas lack adequate drainage. High water tables in this area may limit nonagricultural construction. Detailed information and the various alluvial soil series in the flood plains is included in Table B26.

B4.23 The relative advantages and disadvantages of the soil associations within the flood plains for various economic uses were based upon soil survey data collected by the U. S. Soil Conservation Service.

B4.24 The Palmyra Association is the predominant soil group in the bottomlands between North Pembroke and Alexander in the Tonawanda Creek Valley. This association is made up chiefly of well-drained, gravelly soils on glacial outwash terraces and of loamy soils on flood plains. It occurs in the southern half of Genesee County. The largest tract of glacial terraces in the county extends along the east side of the Tonawanda Creek Valley from the city of Batavia to the village of Attica. In areas having favorable slopes, the soils on terraces are excellent for farming and so are the alluvial soils which occur on the flood plains. These soils are fertile and productive but are susceptible to frequent flooding.

B4.25 Genesee silt loam is a deep, medium-textured soil within the Palmyra Association which occupies well-drained flood plains and is the most productive soil in the county. It has a very high moisture-supplying capacity and moderate to high natural fertility. This soil is well suited to most crops grown in the county and is especially well suited to row crops. This soil has been utilized more frequently for intertilled crops than for pasture or trees. Row crops can be grown continuously if management is highly skilled. Among the farm practices common to this soil group is liming and fertilizing according to results of soils test and desired yields, as well as minimum tillage of row crops.

B4.26 Other soils of the Palmyra Association, which consists of deep, nearly level, well-drained soils on glacial outwash terraces and uplands, have moderate to high permeability and water-holding capacity. Soils of this group are suited to practically all crops grown in the county. These soils are well suited to all grains and sod crops and can be row cropped successively under proper farm management.

B4.27 Soils of the Wayland series are poorly-drained nearly level soils on flood plains. They are wet and are subject to severe flooding and have a high moisture-supplying capacity and high natural fertility. Row crops require artificial drainage and streambank erosion and stream deposition must be controlled. The most dependable use is for hay or pasture consisting of grasses that are tolerant of periodic flooding.

B4.28 Nonfarm uses of soils on bottom land are severely limited by the risk of flooding. The adjacent glacial outwash terraces offer many excellent sites for residential or industrial purposes. Water is available from underground sources and the soils are sufficiently permeable for disposing of septic tank effluent.

Table B26 - Flood Plain Soil Characteristics

Soil Series	Depth to Bedrock	Depth to Seasonally High Water Tables	Slope %	Septic Tanks Filter Fields	Homesites 1/	Street+ Parking Lots	Play + Picnic Areas	Campsites 2/	Field Crops	Truck Crops	Agricultural 3/ Potential
Hamlin	4+	1.5+	0-3	Severe	Severe	Severe	Moderate	Moderate	Slight	Slight	1
Genesee	20-60	2.0+	0-3	Severe	Severe	Severe	Slight	Moderate	Slight	Slight	1
Eel	4-40	1.5 to 2.5	0-3	Severe	Severe	Severe	Moderate	Severe	Slight	Slight	2
Wayland	6-40	0	0-3	Severe	Severe	Severe	Severe	Severe	Moderate	Moderate	4
Rhinebeck	6+	.5 to 1.0	0-3	Severe	Severe	Severe	Severe	Severe	Moderate	Moderate	3
Raynham	6+	.5 to 1.0	0-3	Severe	Severe	Severe	Moderate	Severe	Moderate	Moderate	3
Odessa	6+	.5 to 1.0	0-6	Severe	Severe	Severe	Moderate	Severe	Moderate	Moderate	3
Lakemont	6+	0 to 1.5	0-6	Severe	Severe	Severe	Severe	Severe	Severe	Severe	4
Canandaigua	6+	0 to .5	0-2	Severe	Severe	Severe	Severe	Severe	Moderate	Moderate	3

1/ Includes homes with basements.
2/ Utilized by tents and trailers.
3/ Rating for agricultural use is based on agricultural capability classification established by Soil Conservation Service. Highest possible rating is 1; lowest rating is 8.

SOURCES: Soil Survey of Genesee County, New York, U. S. Department of Agriculture, Soil Conservation Service.
Soil Survey of Niagara County, New York, U. S. Department of Agriculture, Soil Conservation Service.
Soil Survey of Wyoming County, New York, U. S. Department of Agriculture, Soil Conservation Service.

B4.29 The primary soil association of the flood plain between the Tonawanda Indian Reservation and the New York State Barge Canal is the Canandaigua-Raynham-Rhinebeck Association. The soils in this association are level and occur in areas that border Tonawanda Creek in the extreme southern part of Niagara County. The association extends westward to the city of North Tonawanda and into portions of Wheatfield and Niagara Falls. This association occupies 11 percent of Niagara County; 26 percent of this association consists of Canandaigua soils, 23 percent is Raynham soils, and 17 percent is Rhinebeck soils. The remaining 34 percent is made up of minor soils.

B4.30 Canandaigua soils are deep and poorly-drained to very poorly-drained and occupy broad level areas. Rhinebeck soils are also nearly level, occupy broad areas, are deep and somewhat poorly drained. Raynham soils occupy the slightly higher elevations and normally are closely associated with the Canandaigua soils.

B4.31 This association has medium to low value for farming. Community or farm development is limited mainly by natural drainage. The flatness of the area is the main consideration in planning drainage; group drainage projects are needed in many places to provide suitable outlets. Most of the farmlands are not farmed intensively. Where adequate drainage is provided, the crop potential is good for hay, grain, and certain vegetable crops. In most places the soils are stone-free and vegetables can be grown intensively in many areas if extensive tilling is practiced.

B4.32 Soils in this association were deposited by glacial lakes and include wet, compressed and unstable layers. Care must be taken in constructing foundations for buildings and roads. Most of this association is open land but small forested areas remain as woodlots. Vegetation on some idle farmland is now reverting to ash, soft maple, and other native hardwoods.

B4.33 The Canandaigua-Raynham-Rhinebeck Association also extends southward into Erie County. Smaller portions of the flood plain are occupied by the Odessa-Lakemont Association which consists of red clayey, poorly drained, limey lacustrine soils. Agriculture is possible if extensive systems of tile drains are used. Drainage ditches work well in some areas but their usefulness is offset by the general flatness of this portion of the floodlands. Croplands devoted to corn and oats are common in the eastern portion of the town of Clarence and throughout the town of Newstead. Extensive community development in northern Erie County is hampered by a very high water table in this area.

(3) Mineral Resources

B4.34 Mineral production in Erie, Niagara, Genesee, and Wyoming Counties is reflected in Table B27. Mineral resources in the watershed include salt, gypsum, limestone, dolomite, and natural gas. Salt beds of the watershed are principally located in Wyoming County and are mined by the Morton Salt Corporation using an evaporation process. Most of the salt recovered by this method is used in the food processing industry and in

various seasonings. Some salt is also used in the manufacture of chlorine and other chemicals. Salt mining is centered in the southwestern portion of Wyoming County near the village of Silver Springs which lies outside the watershed.

Table B27 - Mineral Production by County

County	1971 ($000)	1972 ($000)	Minerals Produced in Order of Value in 1972
Erie	12,911	12,294	Stone, lime, sand/gravel, gypsum, natural gas, clays
Niagara	(D)	(D)	Stone, lime, sand/gravel
Genesee	(D)	3,517	Gypsum, stone, sand/gravel, natural gas
Wyoming	(D)	(D)	Salt, natural gas

(D) Data withheld to avoid disclosure.

SOURCE: New York State Statistical Abstract - 1974, New York State Division of the Budget, Office of Statistical Information.

B4.35 Minimal amounts of salt are also mined by Hooker Chemical Corporation in the Little Tonawanda Creek Valley, near the village of Dale. Little information was available describing the operation; it is likely that salt mined there is used at chemical plants in Niagara Falls. Wyoming County is one of the top three producers of salt mined from wells in New York State.

B4.36 Quarrying of limestone and dolomite in the Tonawanda Creek Watershed is concentrated along the Onondaga and Niagara Escarpments in Erie and Niagara Counties. Production statistics since 1969 have indicated an increase in the quantity and value of stone products mined in this area. Stone products produced in this area are used as riprap, flux, concrete aggregate, and railroad ballast.

B4.37 New York's position as a leader in sand and gravel production is in large part attributed to its position within the area covered by the last glacier. Commercial sand and gravel formations were deposited by streams of sediment-laden meltwater entering glacial lakes. Sand and gravel resources in western New York, representative of parent bedrock, are high in lime content. Sand and gravel operations are scattered throughout the watershed and are dependent upon the degree of construction or roadbuilding activity. Stability of the sand and gravel industry is greater near large urban centers than the smaller towns and villages in more remote portions of the watershed. Demands of small communities for sand and gravel tend to fluctuate significantly. The majority of quarried sand and gravel is washed and screened for use in structural and paving concrete. Fill, industrial sands, and railroad ballast account for most of the remainder.

B4.38 Sand and gravel operations tend to be small and serve local construction demands. High weight and bulk combined with low unit value of sand and gravel limits the market area. Approximately seven operators presently supply the demand generated by construction activities in the city of Batavia. Many more abandoned sand and gravel mines can be found in the watershed and there is no shortage of sand and gravel resources in this region. Supply problems may develop in the vicinity of urbanizing areas because sand and gravel-bearing lands are usually areas of good drainage which are often zoned for building construction (residential) and other uses excluding mining.

B4.39 Mining of gypsum has historically occurred along the Onondaga Escarpment from Madison County on the east to Erie County on the west, a distance of 165 miles. High-grade gypsum suitable for calcined building products is currently mined in portions of Erie and Genesee Counties that also lie within the watershed. Mining activity has been limited to beds usually within the upper 100 feet of the Camillus formation. Production statistics maintained by the U. S. Department of Interior, Bureau of Mines, indicates that annual production of crude gypsum and manufacture of gypsum-related products has fluctuated widely since 1969. At present, there is no active gypsum mine in the watershed, although National Gypsum Corporation continues to maintain its Clarence Center Mine on a standby basis. This industry is especially sensitive to cyclical changes in residential construction. As a result, many gypsum mining and manufacturing plants in Erie County have gone out of business.

B4.40 Five natural gas fields underlie portions of the Tonawanda Watershed. One field is under the towns of Attica and Bennington in Wyoming County. A second field is located beneath the towns of Darien and Pembroke in Genesee County. A third field underlies portions of the towns of Pembroke and Newstead in Genesee and Erie Counties. The fourth and largest field underlies portions of Alden, Newstead, Clarence, and Lancaster in Erie County. The fifth field is underneath the towns of Amherst, Tonawanda, and North Tonawanda in Erie and Niagara Counties. Most producing wells in this field were capped during the 1960's due to low yields and high operating costs. These natural gas fields serve a dual purpose; to store natural gas piped in from other areas and to tap into regional gas deposits under western New York.

B4.41 The greatest economic impact of these mineral resources in the watershed occurs between April and November. During this eight month period, general construction activities reaches its seasonal peak and employment at mines and quarries increases substantially. Based upon recent employment and average wage rates in this industry, total payroll costs were estimated to exceed $1.4 million dollars in 1970. In addition, mines and quarries contribute to the tax base of numerous villages and towns. The role of these mineral-related activities in the area is projected to increase in the future. The respending of these wages earned in these activities in the watershed produces a final economic impact equivalent to a multiple of the original wages. This phenomena is described as the "multiplier effect."

(4) Water Resources

B4.42 Groundwater Resources

(a) Groundwater throughout the watershed is available in quantities sufficient to supply individual users for domestic purposes. In a few areas groundwater resources are capable of supporting municipal water supply systems. The city of Batavia is currently obtaining 50 percent of its total water requirements from groundwater sources. High yields of groundwater in this area are related to the extensive aquifers composed of glacial sand and gravel between the village of Attica and the city of Batavia. Limestone and dolomite bedrock downstream from the city of Batavia produce moderate to high yields. Only small yields are available from the remaining shales, lacustrine soils and glacial till. Sand and gravel deposits have high potential for development, since recharge rates range from one-half to four million gallons per day per square mile of surface area. To this potential should be added infiltration from streams that could be induced by pumping out large quantities of groundwater.

B4.43 The quality of groundwater in the watershed upstream from the city of Batavia is marked by a high hardness but generally not by other unfavorable characteristics. Groundwater in the area between the city of Batavia and the mouth of Tonawanda Creek is harder and otherwise poor in quality. The water in the Camillus Shale (the predominant bedrock in the area downstream from the Onondaga Escarpment) is objectionably high in sulfates and, in some areas, chlorides. The chlorides may be dissolved out of deeply buried salt beds by water moving through a regional flow system from a recharge area in the Appalachian Uplands to a discharge area along Tonawanda Creek. Shallow groundwater from carbonate rocks and sand and gravel deposits locally have often been polluted by septic tank effluent.

B4.44 Surface Water Resources

(b) Large variations in rainfall occur within the watershed. Average annual rainfall in the Appalachian Uplands upstream from the city of Batavia reaches 44 inches while most of the watershed receives approximately 32 inches of rainfall annually. Rainfall attributed to storms does not vary significantly over the watershed. Stored surface water includes only a few small deepwater bodies and several large shallow-water bodies. Suitable physiography for deep-water storage exists only in the Cattaraugus Hills. Faun Lake, located in the headlands of the East Fork of Tonawanda Creek in the town of Wethersfield, is the largest natural deep-water body in the upland area. Few man-made water storage areas are located in the area; the largest is the Upper Attica Reservoir which has a surface area of 200 acres. The lowlands in the watershed are occupied by many swamps and wetlands which provide natural surface storage for spring runoff and intense precipitation.

(5) Vegetation

B4.45 Natural vegetation associations within the watershed have developed in response to three major determinants: climate, soils, and the degree and kinds of disturbances that have occurred. This last factor was

greatly influenced by the agrarian-oriented settlers of the area. Recently, urbanization of certain areas of the watershed have become an important influence in determining types of vegetation.

B4.46 Differences in climate account for the broad range of vegetation in the watershed, since plants respond primarily to the number of days in the growing season and fluctuations in temperature during the growing season.

B4.47 Differences in soil, especially in water retaining capacities, but also in chemical content, result in localized differences in vegetation. Plant associations have developed partially in response to wetness of the soil. Seasonally wet areas display a marshy meadow kind of vegetation made up of grasses and sedges. In better drained areas, shrubby plants are more numerous and various bushes and bushy trees are taking over.

B4.48 Large areas of New York State are in some stage of recovery from the impact of the early settlers. Land originally cleared for farming has recovered slowly and supports the general plant types and successions expected on unfavorable soils. This sort of succession may take many years, but eventually idle land will become reforested.

B4.49 The watershed within Erie and Niagara Counties and the majority of Genesee County supports the Elm-Red Maple-Northern Hardwood Association. The remainder of the watershed in Wyoming County supports the Northern Hardwood Association. The widespread poorly-drained areas together with the nearly complete removal of the natural forest on the lake plains has produced an area distinct from other forest zones which surround it. Vegetation in the area is distinguished by the relative frequency of American Elm and Red Maple, although both oak and northern hardwoods are still present in lesser abundance. The amounts of oak are especially reduced because the well-drained soils which it prefers have been cleared and are generally in use for growing crops or for pasture. Farmers were originally attracted to this area by its rolling terrain, its good soils, and its accessibility to major transportation routes. The remainder of this area, not currently used for farming, provides a good habitat for the elm and red maple.

B4.50 The Northern Hardwood Association is the predominant vegetative association in Wyoming County and contains occasional stands of oaks. However, the short growing season (150 days) and the moderate temperatures do not enable them to compete successfully. On the other hand, this area appears to be too warm and dry for spruce or fir. This forest association extends into the southeastern portion of Erie County and into Pennsylvania. Northern hardwoods do not penetrate westward to the Great Lakes Plains due to the warmer climate which encourages oaks and other trees to mix in.

B4.51 The Northern Hardwood Association is not uniform but is made up of large groups of trees dominated by beech and sugar maple. Beech, black cherry, and oak are most common where drainage is good whereas maple, ash, and elm are more numerous in flood plains.

(6) Climate

B4.52 The climate in the vicinity of the Tonawanda Creek Watershed is moderate and humid. Average monthly temperatures range from approximately 25°F in January to 70°F in July. Air above the watershed is usually brought in by westerly winds carried at low elevation over Lake Erie where it picks up considerable moisture. Before this air reaches the watershed, it is carried over northern parts of the Appalachian Uplands, which lift and cool it and cause it to precipitate much of its moisture. Thus, the lowlands of the watershed lie in a precipitation "shadow" and receive considerably less precipitation than adjacent uplands to the southwest. Within the watershed, intense precipitation usually occurs only in summer, most commonly in the form of thunderstorms in June, July, and August. Approximately 30 thunderstorms occur over the watershed annually. The time distribution of precipitation is fairly uniform; the watershed receives approximately three inches per month. Annually, the watershed receives approximately 34 inches of water, including approximately 76 inches of snow.

(7) Wildlife

B4.53 Warmwater fishery resources predominate in Tonawanda Creek from its mouth upstream to the village of Attica. Smallmouth and largemouth bass, northern pike, walleyes, pan fish, and suckers are found in this area. Lower air temperatures plus an abundance of groundwater allow coldwater species to predominate in the upland areas of the watershed in the towns of Sheldon, Orangeville, Java and Wethersfield. Brown trout are the primary coldwater species but brook and rainbow trout also find suitable habitats in these areas.

B4.54 There are no large inland lakes in the watershed. The largest areas of impounded waters are the Upper Attica reservoir (200 acres), Indian Falls Lake (30 acres), and Faun Lake (45 acres). Faun Lake is the largest natural deep water body in the upland and is located in the headlands of the East Fork of Tonawanda Creek in the town of Wethersfield. Public access and fishing is prohibited at the Upper Attica Reservoir and Faun Lake. Most residents in the area look outside the watershed for fishery resources. North and west of the watershed Lake Ontario and Lake Erie provide a large fishery resource but lack extensive public access, experience severe lake winds, and have water quality problems which have resulted in shifts toward lower quality fish species. All of these factors contribute to limited usage by the general public.

B4.55 The density of aquatic wildlife species in the watershed are influenced by the abundance of surface water and the variety of aquatic vegetation. Most waterfowl which migrate through the area nest in three major game management areas (Tonawanda Game Management Area, Iroquois National Wildlife Refuge and the Oak Orchard Creek Wildlife Area). Aquatic amphibians and reptiles including turtles, snakes, frogs, toads, and salamanders are common in the marsh and wetland habitats maintained within these three areas.

B4.56 Factors affecting the density of these species include woodlot size, density of humans, and vegetation by type and successional stage. These factors, in conjunction with climate, influence the range of species. The woodlots of the watershed provide good habitat for game and furbearing species typical of cut-over hardwoods in New York State. Common woodland wildlife species include whitetail deer, grouse, and squirrels. Their densities per acre vary depending upon the local habitat.

B4.57 Open land and agricultural wildlife species find food in fields close to woody vegetation (hedgerows, forest edges, etc.) which provides escape and winter cover. The type of agriculture and management practices are important factors determining habitat suitability. Elimination of hedgerows, early mowing, and fall plowing are some practices detrimental to open land wildlife. Agricultural land management practices within the watershed limit populations of species, such as ringneck pheasant, which depend on high grain production for high densities.

B4.58 Hunting opportunities in the watershed are limited because much of the land where game species live is posted and hunter-use is generally limited to land owners and their friends. Most public hunting occurs on the adjoining public wildlife management areas.

(8) Water Transportation

B4.59 The lower 11.2 miles of Tonawanda Creek is a component of the New York State Barge Canal System. The modern system, referred to as the Barge Canal, roughly parallels the course of its predecessor, the old Erie Canal and enables water traffic to move from the Hudson River to Buffalo providing water transportation service to many economic centers adjacent to the canal.

B4.60 The Erie Canal was enlarged between 1834 and 1862 and continued to be a significant factor in the economic development of New York State. Freight transported on the canal reached two million tons nearly every year from 1860 to 1900 with 4.5 million tons moved during the peak year of 1880. During the period 1905-1918, the Erie Canal was modernized and incorporated into the New York State Barge Canal System. Canalized rivers and lakes form the main units of the new system. Although the Barge Canal has always been a disappointment in terms of volume of traffic it carried and the revenue it produced, substantial amounts of petroleum products, sand and gravel, cement, grain, stone, and other heavy bulk commodities continue to be shipped on it. The maximum size of a float (barge and tug or motorized vessel) that can pass through a lock on the canal is: length 300 feet, beam 43.5 feet; and height above water 15 feet. These dimensions apply to a tug with a barge of 2,500 tons capacity. Annual tonnages shipped on the canal are shown for selected years from 1900 to 1973 in Table B28. Currently, the Barge Canal carries approximately one million tons of waterborne cargo each year.

B4.61 Pipelines, railroads, bulk trucking facilities, and the Saint Lawrence Seaway System contributed heavily to the demise of the Barge Canal. The New York State Barge Canal System today, in addition to its role in commerce, serves as a water resource and drainage system for areas of central and western New York. Canal water has also been used for irrigation,

industrial needs, and generation of electricity in western New York. However, its most significant use today is for recreational boating. The system has experienced a dramatic increase in the number of pleasure craft during the past two decades and the canal may eventually be maintained for noncommercial purposes alone.

Table B28 - New York State Barge Canal
Annual Tonnage for Selected Years

Year	Annual Tonnage
1900	2,145,876
1910	2,023,185
1920	891,221
1930	3,044,271
1935	3,898,506
1940	3,587,086
1945	1,665,447
1950	3,620,346
1955	2,779,491
1960	1,772,789
1965	1,508,546
1970	983,982
1971	926,278
1972	789,142
1973	896,630

(9) Recreation Facilities

B4.62 Detailed information describing recreation facilities available within the watershed was based upon a facility survey by the New York State Parks and Recreation Department as part of a larger Statewide Comprehensive Outdoor Recreation Plan. A report of the survey results was published in 1972 and contained detailed information concerning capabilities and activities available at each recreation site. Sixty public and privately-owned sites consisting of more than 21,500 acres lie within the Tonawanda Creek Watershed.

B4.38 Sand and gravel operations tend to be small and serve local construction demands. High weight and bulk combined with low unit value of sand and gravel limits the market area. Approximately seven operators presently supply the demand generated by construction activities in the city of Batavia. Many more abandoned sand and gravel mines can be found in the watershed and there is no shortage of sand and gravel resources in this region. Supply problems may develop in the vicinity of urbanizing areas because sand and gravel-bearing lands are usually areas of good drainage which are often zoned for building construction (residential) and other uses excluding mining.

B4.39 Mining of gypsum has historically occurred along the Onondaga Escarpment from Madison County on the east to Erie County on the west, a distance of 165 miles. High-grade gypsum suitable for calcined building products is currently mined in portions of Erie and Genesee Counties that also lie within the watershed. Mining activity has been limited to beds usually within the upper 100 feet of the Camillus formation. Production statistics maintained by the U. S. Department of Interior, Bureau of Mines, indicates that annual production of crude gypsum and manufacture of gypsum-related products has fluctuated widely since 1969. At present, there is no active gypsum mine in the watershed, although National Gypsum Corporation continues to maintain its Clarence Center Mine on a standby basis. This industry is especially sensitive to cyclical changes in residential construction. As a result, many gypsum mining and manufacturing plants in Erie County have gone out of business.

B4.40 Five natural gas fields underlie portions of the Tonawanda Watershed. One field is under the towns of Attica and Bennington in Wyoming County. A second field is located beneath the towns of Darien and Pembroke in Genesee County. A third field underlies portions of the towns of Pembroke and Newstead in Genesee and Erie Counties. The fourth and largest field underlies portions of Alden, Newstead, Clarence, and Lancaster in Erie County. The fifth field is underneath the towns of Amherst, Tonawanda, and North Tonawanda in Erie and Niagara Counties. Most producing wells in this field were capped during the 1960's due to low yields and high operating costs. These natural gas fields serve a dual purpose; to store natural gas piped in from other areas and to tap into regional gas deposits under western New York.

B4.41 The greatest economic impact of these mineral resources in the watershed occurs between April and November. During this eight month period, general construction activities reaches its seasonal peak and employment at mines and quarries increases substantially. Based upon recent employment and average wage rates in this industry, total payroll costs were estimated to exceed $1.4 million dollars in 1970. In addition, mines and quarries contribute to the tax base of numerous villages and towns. The role of these mineral-related activities in the area is projected to increase in the future. The respending of these wages earned in these activities in the watershed produces a final economic impact equivalent to a multiple of the original wages. This phenomena is described as the "multiplier effect."

recreation activities. The potential recreation value of open space corridors (OSC) along Tonawanda Creek and its major tributaries was recognized by ENCRPB in its 1971 recommendations to develop riverine areas under the region's recreation plan. However, inland streams offer limited water recreation possibilities because of their small size and low sustained summer flows. The few inland lakes and reservoirs offer limited water-oriented recreation use. The largest inland lake currently developed is Indian Falls Lake Park in the town of Pembroke. This facility is privately owned and operated and consists of a 90-acre area, including a 4-acre playground and an archeological site.

B4.68 The Genesee County Planning Board published an open space and recreation report in December 1974 to identify recreation needs in the county, a substantial portion of which is in the watershed. This report identified eight areas in the county for possible acquisition and development by the county Government. Specific time tables for acquisition and development are not available.

B4.69 Three of these areas (Divers Lake, a small waterfall site on Little Tonawanda Creek in the town of Bethany, and that portion of Tonawanda Creek between the city of Batavia and the village of Alexander) are within the watershed. However, only the Bethany site and the area included between Batavia and Alexander would be within the Intermediate Regional Flood Zone.

B4.70 Divers Lake is a natural impoundment of approximately six acres surrounded by woodlands and gentle rolling farmland. This is a good area for water-based recreation, trail sports, and picnicking. Within the town of Bethany on Little Tonawanda Creek there is a scenic area consisting of a heavily wooded gorge and a 50-foot waterfall proposed for inclusion in a single purpose linear park. Limited roadside picnicking and trail sports as well as a scenic outlook would be the principal activities. A linear park is also planned for the area adjacent to Tonawanda Creek between the cities of Batavia and village of Attica. Both sides of the creek are partially wooded and portions of the adjacent agricultural lands contiguous to the creek would provide areas for hiking and picnicking. A canoe trail is tentatively planned for this section of Tonawanda Creek.

B4.71 Numerous tributaries of Tonawanda Creek in the towns of Amherst, Clarence, and Newstead are actively promoted by ENCRPB as ideal areas for OSC's. Approximately 2,400 acres of land along Tonawanda Creek, Murder Creek, Beeman Creek, Black Creek, Mud Creek, and areas along the New York State Barge Canal were proposed for OSC's by ENCRPB. Preservation of lands adjacent to these streams could provide recreation opportunities such as wildlife areas, limited boating and canoeing, fishing, and hunting. Because their locations are within easy driving distance of large centers of population, they constitute principal sources of recreation land for residents in the Buffalo SMSA and the Tonawanda Creek Watershed. Preservation of areas contiguous to streams would also provide recreation opportunities nearer to the region's population than existing parks and recreation facilities have in the past. An added incentive to developing OSC's in floodprone areas is the preservation of unique natural features and natural wildlife habitats. In light of extensive undeveloped areas within the watershed, additional vacant

areas which might result from relocation or permanent evacuation of existing residential units were not considered to result in a significant or unique addition to the existing supply of potential recreation acreage. Therefore, recreation benefits were not derived for the development of such areas.

B4.72 Extensive wooded areas upstream from the town of Clarence that are in the flood plain have good potential for recreational use. These areas could provide sites for hunting, picnicking and other opportunities. Unfortunately most of these wooded areas are not close to urbanized portions of the watershed.

B4.73 Forecasts of outdoor recreation prepared by the New York State Department of Parks and Recreation have established that in each of the four counties within the watershed, the greatest absolute increase in recreation demand will occur in swimming and picnicking.

B4.74 Planning standards used by ENCRPB and other local agencies are oriented to 25 acres of public recreation space for each 1,000 people in the region. Based upon OBERS Population projections the resident population in the Buffalo SMSA will increase by 170,703 requiring an additional 4,300 acres of recreation space just to maintain the regional standard of 25 acres/1,000 residents. The central position of the Tonawanda Watershed and its floodprone areas will undoubtedly play an important role in providing much of this needed increase in park facilities. Open space corridors, trailways along powerline easements or abandoned railways, wilderness, and nature preserves could be located at various points in designated flood hazard areas.

B4.75 *Increased participation in outdoor recreation* by the region's population will be centered in swimming and picnicking, Table B29. Substantial portions of the watershed, could easily be developed for supplying additional picnic areas, however, most residents in the area will continue to travel outside the watershed to participate in water-related recreation.

c. Available Services.

(1) Highways

B4.76 The population of the Tonawanda Creek Watershed is concentrated in and around the following major cities: Buffalo, Niagara Falls, North Tonawanda, Lockport, Batavia, and the town of Tonawanda. Each city's population density decreases with distance from the center of its CBD and there is an even spread of settlement in the rural areas. Three major regional transportation networks link urban areas within the watershed. They are the canal system, the railroad network, and the road network on which both people and goods are carried by bus, automobile, and truck.

B4.77 The New York State Barge Canal was partially constructed along the course of the former Erie Canal. The existing facility utilizes the Tonawanda Creek channel for the lower 11.2 miles. It has a navigable depth of 12 feet, a navigable width of 75 feet, and a total width of approximately 200 feet.

Table B29 - Projected Increase in Recreating Population for Selected Counties (1970-1990)

County	Swimming	Picnicking	Camping	Boating	Skiing	Hunting	Fishing	Golfing	Local Winter Activities	Neighborhood Activities
Wyoming	1,708	3,519	862	-253	203	172	1,617	1,007	-349	1,251
Genesee	8,016	5,744	1,407	2,330	1,771	521	1,892	2,185	1,344	3,542
Niagara	12,506	8,620	2,439	2,955	4,265	-1,095	2,411	5,720	-1,512	2,415
Erie	86,508	51,821	16,692	37,333	30,864	2,499	15,267	24,317	12,973	30,077

SOURCE: Forecast of Outdoor Recreation in New York State
New York State Parks and Recreation Department

B4.78 Water levels in the canalized section of the Tonawanda Creek channel depend chiefly on the stages of the Niagara River at Tonawanda, NY, which are affected by wind and barometric conditions over the Niagara River and Lake Erie. During the navigation season from April to December approximately 1,100 cfs are diverted from the Niagara River easterly via Tonawanda Creek to the Barge Canal to combine with normal east-west flow in Tonawanda Creek. This water is necessary for operation of locks and maintenance of water levels east of Lockport, NY. During other months a gate is closed on the Barge Canal at Pendleton which allows the creek to flow naturally to the Niagara River. Commercial navigation has declined considerably on the canal. Today, the prime users of this facility are recreational boaters.

B4.79 There are approximately 689 miles of highway in the watershed consisting of 50 miles of Federal highway, 239 miles of State highway and 400 miles of county roads. In addition, there are many city and town roads. Urban and nonurban areas have excellent highway transportation networks.

B4.80 Genesee County, with the exception of the city of Batavia, consists mainly of farmland, therefore, the road system is not as extensive as that found in major urban areas in Erie County. The road network is considered adequate to serve the needs of a farm-oriented county.

B4.81 Of the four counties within the watershed, Erie County has the highest population density and the highest concentration of roads. Public transportation in Erie and Niagara Counties and, to a lesser degree, Genesee County, is of particular importance to densely populated areas where many people have no other means of transportation. Although development of public transportation service in intracity areas has been extensive, availability of public transportation rapidly decreases with distance from the CBD's of the cities.

B4.82 There are several private airports within the watershed which are used for recreational purposes and do not provide service to scheduled carriers. Their impact on transportation within the watershed is insignificant.

(2) Railroads

B4.83 The existing rail network in the flood plains is operated by Conrail Corporation and consists of the Penn-Central, Lehigh Valley, and Erie-Lackawanna trackage. Rail service is predominantly east-west oriented with major north-south linkages located in the Buffalo (Baltimore & Ohio, Norfolk & Western, and Conrail) and Batavia (Conrail and Baltimore & Ohio) areas.

B4.84 Rail service in western New York, as well as the entire northeast, has been reorganized under the Regional Rail Reorganization Act of 1973 (RRRA). Under this Act, the United States Railway Association has recommended a rail network comprising three major integral systems: Conrail, with Penn-Central as its core and including elements of smaller carriers now in reorganization; an expanded Chessie system that would extend eastward into western New York; and the Norfolk & Western combined with smaller solvent

carriers possibly operating some new trackage and providing some additional services. Reorganization of existing railroads into an efficient self-supporting system has resulted in large-scale abandonment of light density branch lines.

B4.85 Most of the existing trackage in or immediately adjacent to the flood plains has been included in the Conrail network. Western New York railroads are shown in Plate B6. Other lines in or near the flood plains which were earlier scheduled to be abandoned were later considered for inclusion in the Conrail or Chessie systems and are not referred to here.

B4.86 In general, the flood plains possess adequate rail service and the overall impact of the Regional Rail Reorganization Act on western New York will not be significant in the long run. There will be some dislocations and some firms will be forced out of business. In the long run, the proposed organizational structure not only can help the region's carriers function more efficiently and economically than they have in the past, but can also serve industry by providing a more competitive mode of transportation.

(3) Water Supply and Waste Treatment

B4.87 Use and the demand on western New York's water resources has been increasing. The increase in water use and the resultant increase in waste water is due to population growth and development of an industrial economy. In addition, changing life styles, increased affluence, and new technologies which require increasing amounts of raw water also increase the amount of waste water generated. The principal demands for raw water are for public, private, and industrial water supply systems, waste assimilation, irrigation, wildlife, and livestock watering, fish and aquatic life, recreation, cooling, navigation, and hydroelectric power.

B4.88 The availability of water within the region is not limited to abundant surface supplies contained in the adjacent Great Lakes and streams. Large stores of groundwater underlie western New York. However, groundwater resources are generally not sufficient to serve as an adequate sole source of water supply for major urban areas and large water using industries. In those areas where the groundwater is relied upon to meet local needs, the natural limits of groundwater supplies can be very effective in controlling new development.

B4.89 Table B30 indicates the locations and sources of raw water and capacities of major water treatment plants serving the Tonawanda Creek flood plains. The water treatment plants using the Niagara River and Lake Erie as water sources have an almost unlimited supply. However, these plants are limited in their expansion capabilities. Eventually, smaller plants such as those now serving the town of Tonawanda and Grand Island will be phased out. Low capacity water treatment facilities will be replaced by large, economical regional facilities.

B4.90 Inland water supplies depend upon groundwater sources which have quantity, quality, and availability limitations. Groundwater often requires

Table B30 - Water Treatment Facilities for Selected Areas

Location	Existing Capacity (mgd)	Ultimate Capacity (mgd)	Raw Water Source	Comment
Niagara County Water District	20	114	Niagara River	Regional Facility
North Tonawanda	12	12	Niagara River	
Tonawanda	8	8	Niagara River	Phase Out
Grand Island	1.5	1.5	Niagara River	Phase Out
Town of Tonawanda	24	136	Niagara River	Regional Facility
Lockport	12	12	Niagara River	
Akron Village	0.58	0.58	Reservoir	Phase Out
Akron Village	0.21	1.21	Ground Water	Phase Out
Attica	1.20	1.20	Reservoir	Phase Out
Batavia	6.0	6.0	Ground Water and Tonawanda Creek	Will be Expanded

SOURCE: Adopted Regional Water Supply, Plan and Program, 1973, Erie and Niagara Counties Regional Planning Board.

additional treatment such as softening and demineralization which increase user-costs. The remainder of Erie County, except Akron which obtains its raw water supply from a reservoir located in Wyoming County, uses groundwater. Eventually these systems will be phased out and these areas will be served by the county-wide water authority systems.

B4.92 The four water treatment facilities in Niagara County also utilize the unlimited supply of the Niagara River. The proposed plants are designed to draw water from Lake Ontario, however, these plants will not serve the flood plains. The two proposed plants will be located in the villages of Olcott and Youngstown. They will service the area south of the Niagara Escarpment and are scheduled for completion between 1990 and 2000. Public water supply facilities serving the flood plains are currently located in North Tonawanda, Lockport, and Wheatfield. The Wheatfield facility serves all remaining areas in Niagara County that do not otherwise rely on individual water wells.

B4.93 Genesee County water supply authorities obtain their water from wells, creeks, or from reservoirs in Wyoming County. The largest water treatment plant in Genesee County is located in the city of Batavia. This plant relies on raw water from Tonawanda Creek and two auxiliary wells. The city plans to increase its dependence on groundwater and substantially reduce its use of Tonawanda Creek. Virtually all rural areas obtain their water supply from public or private wells, except for the village of Alexander which purchases water wholesale from the village of Attica.

B4.94 In the future, portions of Genesee County may receive their water from Lake Ontario, possibly through the Monroe County Water Authority. The future of small independent water systems is limited since these systems are increasingly difficult to operate efficiently. This is a result of increased costs to maintain high levels of quality and reliability of service.

B4.95 The increase in water usage over time has resulted in a substantial increase of wastewater and reduced water quality in western New York lakes, rivers, and streams. The regions wastewater treatment facilities are often unable to process wastewater effectively enough to meet New York State and Federal water quality standards. The region's wastewater treatment facilities are being upgraded, expanded, and consolidated to comply with existing standards. There are approximately nine public sewage treatment facilities serving the Tonawanda Creek Watershed, in addition to numerous industrial and other private waste treatment facilities.

B4.96 The most extensive sanitary system in the flood plains is located in the Buffalo urban area. More easterly areas rely heavily on septic systems or small scale municipal systems. Table B31 lists the existing public wastewater treatment facilities serving the flood plains.

B4.97 One major wastewater treatment plant now under construction in the flood plain is that of Amherst Sewer District 16 which should be in operation by 1980. This plant will eventually serve western portions of the lower flood plain.

Table B31 - Sanitary Sewage Systems for Selected Areas

Location	Type	Existing Capacity	Ultimate (mgd)	Comment
Wheatfield	Activated Sludge	-	36.0	Under construction
North Tonawanda	Activated Sludge	13.0	35.0	
Amherst SD #16	Activated Sludge	6.0	48.7	
Amherst SD #1	Trickling Filter	6.3	6.3	
Town of Tonawanda	Incinerator (Secondary)	30.0	48.7	Activated sludge expansion underway
City of Tonawanda	Primary, Tank	6.0	6.0	Will become pumping station
Akron	Trickling Filter	0.37	0.37	Future site of pump station
Batavia	Activated Sludge	2.5	2.5	Under study for expansion
Alexander	Trickling Filter	0.2	0.2	Under study for expansion

SOURCE: Regional Sanitary Sewage Plan and Program, 1972 Erie and Niagara Counties Regional Planning Board.

B4.98 The city of Batavia sewage treatment plant is currently under study for upgrading and expansion. The immediate effect of these efforts will be to provide public sewer systems to areas not previously serviced and to significantly improve the overall quality of effluent. Several obsolete treatment plants will be eventually phased out as outlying areas tie into large consolidated sewer districts. All major population centers and most suburban areas will have public sanitary sewer service by 1990.

d. Labor Force.

B4.99 The labor force of Erie, Niagara, Genesee, and Wyoming Counties numbered approximately 573,485 in 1970. This represents about 57 percent of the population sixteen years old and over in the area. Table B32 presents general labor force participation data for the four county area.

Table B32 - Labor Force Statistics for Selected Counties

	Total Population 1970	Population 16 Yrs and Older	Percent in Labor Force	Total Labor Force	Number Employed
Erie	1,113,491	774,750	57.3	442,867	422,179
Niagara	235,720	161,202	58.0	92,647	87,610
Genesee	58,722	39,516	60.3	23,817	22,548
Wyoming	37,688	25,734	55.0	14,154	13,422
Total	1,445,620	1,001,200	57.3	573,485	545,760

SOURCE: Business Fact Book, Part 2, 1974 Edition, New York State Department of Commerce

B4.100 Manufacturing is the largest employer of resident jobholders in the area as a whole, as well as in each individual county. The strength of this sector has been enhanced by the development of water power in the Niagara Frontier. Nineteenth century manufacturers developed an extensive industrial base along the Niagara River on the basis of abundant water power. Twentieth century industry has also been enhanced by an abundant supply of hydroelectric power generated by the Robert Moses Power Project, one of the largest generating plants in existence.

B4.101 In 1970, one-third of the employed residents in the four county area held manufacturing jobs, slightly above Upstate's 31 percent and much higher than the 24 percent State average. Niagara County had the highest proportion of jobholders in manufacturing - 43 percent in 1970. This is a result of a relatively high ratio of nondurable goods production centering around the manufacture of chemicals.

B4.102 Table B33 lists the occupations of employed persons by county in 1970. The importance of heavy industry, such as steel and automobile production in the Buffalo area, contributes to the high proportion of operatives and craftsmen, and foremen among area workers. These two groups represent the first and third largest job categories in the area.

B4.103 Although manufacturing is the major economic activity in the area, the service industry (business and repair, personal, professional, and entertainment services) is also a significant employer. Approximately 25 percent of the area's working residents listed some facet of the service industry as their employer in 1970.

B4.104 The wholesale and retail trade industry was the third largest employer within the watershed in 1970. The commercial sector accounted for approximately 21 percent of all area jobholders compared with 19 percent for all of Upstate New York. Activities at the port of Buffalo, a high level of tourism in Niagara Falls, and several secondary trade centers within the area contribute to this high proportion of trade employment.

B4.105 Educational systems in Erie, Niagara, and Genesee County provide extensive programs in vocational training, in addition to academic programs, to meet the needs of local industries for technicians, craftsmen, and operatives. Since formal training for such occupations often terminates at the high school level, the median years of school completed by residents 23 years of age and older in 1970 was 12.0, slightly below the Upstate average. About 32 percent of the region's residents finished four years of high school and nine percent completed four or more years of college compared with 33 percent and 11 percent, respectively, for Upstate. Table B34 details educational attainment levels of the four county area compared with Upstate and State datum. In addition to extensive regional vocational educational programs, there are more than a dozen institutions of higher education in the area. One of four State University centers in New York is located in the town of Amherst, adjacent to the Huron plain floodland. The University has an enrollment of 23,000 students currently, but is in the midst of a $1.3 billion expansion program, which when completed will provide facilities for over 40,000 students. The development of a major university complex and significant expansion of several other local colleges during the past decade may have a major long run impact on the labor force in the area. Unless job opportunities become available for the educated sector of the labor force, education may become a leading export industry for this region.

e. <u>Existing Activities</u>.

B4.106 The land use pattern in the Tonawanda Creek flood plain was shown in Plate B2. The western portion of the Huron plain floodland in the vicinity of Buffalo has extensive residential activity, whereas east of the suburbs of Amherst and Clarence it is primarily agricultural or open space. Land use within the Intermediate Regional Flood Plain is shown in Table B35.

B4.107 To facilitate flood damage analysis and evaluation of alternative flood management measures, the damage areas along Tonawanda Creek, Mud Creek, and Black and Ransom Creeks, were divided into 31 reaches. The damage

Table B33 - Employment by Occupation for Selected Counties

Counties	Erie	Niagara	Genesee	Wyoming
Occupation				
Professional, technical, and kindred workers	64,530	11,441	2,928	1,543
Managers and administrators, except farm	30,126	5,655	1,498	864
Sales workers	33,912	5,466	1,265	546
Clerical and kindred workers	76,430	13,648	3,225	1,461
Craftsmen, foremen, and kindred workers	64,587	14,191	3,656	2,203
Operatives, except transport	61,065	17,162	3,885	2,505
Transport equipment operatives	15,993	3,415	1,083	631
Laborers, except farm	19,075	4,080	933	561
Farmers and farm managers	1,142	661	689	777
Farm laborers and farm foremen	970	550	421	655
Service workers, except private household	51,290	10,864	2,775	1,578
Private household workers	3,059	477	190	98
Total employed, 16 years old and over	422,179	87,610	22,548	13,422

SOURCE: New York State, Volume 1, Part 34, Section 1, 1970 Census of Population, U. S. Department of the Census

Table B34 - Education Statistics for Selected Counties

	Median School Years Completed	Percent Completing			
		Four Years High School	One-Three Years College	Four Years College	Five Years or More
Erie County	12.0	30.7	9.7	5.4	4.6
Niagara County	12.0	34.0	8.9	4.3	3.3
Genesee County	12.2	36.8	10.9	5.0	3.0
Wyoming County	12.0	33.1	10.0	4.0	2.7
Upstate	12.1	32.8	10.4	6.0	4.8
New York	12.1	31.2	9.6	6.2	5.6

SOURCE: Business Fact Book, Part 2, 1974 Edition, New York State Department of Commerce

Table B35 - Acreages and Land Use in the Intermediate Regional Floodplains 1/

Land Use Type	T1 to T10 2/	T11 and T12	B1 thru B5	T13	Total
Agriculture					
Active	11,900	1,495 3/	20	3,800	17,215
Inactive	7,900	355 3/	15	30	8,300
Forestlands	5,330	1,465	-	600	7,395
Wooded Wetlands	4,980	3,290	75	735	9,080
Residential	270	45	320	25	660
Commercial & Industrial	70	55	245	-	370
Public and Other	250	5	35	-	290
Total	30,700	6,710	710	5,190	43,310

1/ Stream mile 0.0 to stream mile 78.0.
2/ No overbank flooding from 100-year discharge in Reaches T1 + T2; T1 - T10 includes all tributary reaches.
3/ Most of this acreage is in T11; minimal amount of agricultural land in Reach T12.

SOURCE: New York State Office of Planning Services, Land Use Natural Resources, 1968 Comprehensive Master Plan - City and Town of Batavia, Genesee County Planning Board.

NOTE: Flood plain acreages for agricultural land use do not agree with Table 51 in "Supplement to Appendix B" as a result of more recent and detailed field surveys.

reaches below Hopkins Road (mile 41.5) are within what is referred to as the Lower Tonawanda Creek Watershed and include 10 reaches along Tonawanda Creek (T1 through T10), four reaches along Ransom and Black Creeks (RB1 through RB4) and the six reaches along Mud Creek (M1 through M6).

B4.108 For the 21.2 mile reach between Hopkins Road and the westerly city limit of Batavia, two damage reaches, T11 and T12, were designated. Reach T12 includes the hamlet of Bushville, a small community just west of the city of Batavia. In the city of Batavia, five reaches (B1 through B5) were used to develop damage-frequency relationships. The greatest number of structures within the Standard Project Flood Plain are located in the Huron Plain floodland and in the city of Batavia. There are approximately 5,665 residential, 283 commercial and industrial, and 45 public and other structures within the Tonawanda Creek SPF.

B5. PROJECTED LAND USE WITHIN THE FLOOD PLAINS

B5.1 Existing land use in the 100-year flood plains was presented in Table B35. The largest concentration of floodprone residential development in these flood plains is in Reaches B1 through B5 in the city of Batavia. Other significant centers of residential activity occur along Ransom and Black Creeks in Reaches RB1 through RB4, an area located within the towns of Amherst and Clarence in Erie County.

B5.2 Agriculture is the predominant land use in every reach except T1, T12, and B1 through B5 in the city of Batavia. Extensive tracts of wooded wetlands, forest lands, and inactive agricultural lands are also present in most other nonurban reaches. Generally, the inactive farmlands have not yet developed brush cover. Accurate identification of lands which fall into this category is complicated. Some land may be only temporarily diverted from active use by short-term governmental programs or because of drops in demands for crops raised on it. This same land may be used again for agriculture after one or more years.

B5.3 Flood plain acreage upstream from the Tonawanda Indian Reservation is expected to remain viable for agriculture. Although increased economic activity is projected for the city and town of Batavia, substantial additional urban encroachment into the Intermediate Regional Flood Plain is not expected because of the availability of large tracts of undeveloped land in the northeastern portion of the city and in the town of Batavia contiguous to the city limits. Future residential development is expected to occur outside the city of Batavia and will be served by city water and waste treatment facilities. Local planning officials expect future industrial growth to occur in areas already designated by town and country planners. The largest of these sites is the new industrial park adjacent to Pearl Street. Completion of an urban renewal project in the Central Business District will also increase future levels of commercial activity in Batavia.

B5.4 Availability of sewer and water supplies often spurs industrial, commercial, and residential development since proximity of available utilities to a site greatly increases its potential for development. Dependence upon private utilities (wells and septic tanks) by residents upstream of Reach T10 is high. Only in areas such as the town of Amherst, city of North Tonawanda, and the town of Tonawanda are there extensive networks of municipal sewer and water facilities.

B5.5 Future municipal facilities capable of inducing residential growth into portions of the flood plain will consist of extensions from existing systems located in communities in the western portion of the Huron Plain floodland (i.e., the towns of Tonawanda, Amherst, and Wheatfield and the city of North Tonawanda). These extensions should serve that component of growth expected to extend from the Buffalo Metropolitan Area in easterly and northeasterly directions.

B5.6 At present, the town of Amherst has a more extensive system of municipal services than the town of Clarence, which is only partially served by sewer and water systems. Therefore, the town of Amherst should continue

to outpace Clarence in terms of population growth. Ransom Oaks, a planned community in northeastern Amherst, should remain the site of the largest outlying residential development for many years.

B5.7 The enforcement of floodproofing requirements including the requirement that the lowest floor of all new homes be elevated to 100-year flood elevations, is expected to slow rapid residential growth in this area. Stringent standards imposed by Erie County for new construction may also be a problem in certain areas. Soils in many areas in the town of Clarence, both in and out of the flood plain, are unsuitable, as determined by soil percolation tests required by the Erie County Health Department for installation of individual septic tank systems. Consequently, the extent and timing of growth in residential development in Clarence will depend upon the extension of lateral sewer lines from major collector lines which lie parallel to Transit Road (Route 78). The current philosophy of town residents in Clarence is not oriented towards rapid residential development. Expansion of municipal services or extensions of lateral sewer or water lines into various parts of this town will be ultimately contingent upon approval by town residents of their elected officials. Social factors in this town may be as important as limitations imposed on northern portions of this area by flooding. Table B36 presents estimates of future incremental land use demands by activity under with and without project conditions.

B5.8 Most anticipated land use demands in and out of the flood plains are attributable to future regional growth and population shifts within the Buffalo SMSA. The mature manufacturing economy in the Buffalo Metropolitan Area, coupled with the region's reliance upon heavy industries (steel, automotive parts, and chemicals) have created serious problems which could have strong adverse impacts upon growth in outlying suburban areas. The loss of 38 large manufacturing plants in the Buffalo area between 1970 and 1975 has reduced area manufacturing employment by nearly 10,000 jobs and $125,976,830 in payroll earnings. Also, in 1976 Western Electric Corporation announced the closing of a large manufacturing and assembly plant and the elimination of more than 2,000 jobs. Another area characteristic deterring rapid employment growth is the relatively high cost for industrial labor. The wages for unskilled factory workers in Buffalo are eight percent higher than the national average. Skilled factory workers earn wages that are five percent higher than the national norm. Many of the plants in this area were constructed during World War II and are not as efficient in terms of physical layout and production processes as newer plants in other parts of the country. Also several large firms in the metropolitan area are operated under a system of absentee ownership. This absence of direct social ties to the community by corporate managers or administrators does not create a strong commitment to this region during periods of excess plant capacity or during an economic downturn. Absentee ownership often produces disruptive social impacts to an area when business decisions made outside the area are based solely upon economic considerations.

B5.9 Projections of future incremental land use demand in the flood plains, presented in Table B36, reflect these basic economic problems in addition to physical constraints such as soil limitations and existing flood hazards. Potential users of the greatest acreage in the flood plains are

Table B36 - Projected Incremental Land Use Demand
Use Demand in the 100-Year Flood Plain 1/
1980-2030 (in acres)

	1980-1990		1990-2000		2000-2010		2010-2020		2020-2030		Total
	A	B	A	B	A	B	A	B	A	B	
Residential single family without project	50	10	100	20	150	30	200	40	300	50	950
multi-family without project	25	0	50	0	100	0	225	0	450	0	850
Commercial without project	5	0	10	0	15	0	20	0	25	0	75
Industrial without project	0	0	0	0	0	0	50	0	75	0	125
Recreation & Open Space without project	50	0	100	0	150	0	200	0	250	0	750
Active Agricultural without project	*	*	*	*	*	*	*	*	*	*	*

1/ Incremental land use demand is assumed to proceed from the flood fringe area towards the more frequently flooded areas over the project planning period.

A - includes area downstream from Reach T-9 (includes Erie and Niagara Counties). Development projected to occur downstream of New york State Barge Canal is not included.

B - includes T-10 and all other areas upstream (Genesee and Wyoming Counties).

* - no net land demand based upon historical decline in total acreage farmed in New York State.

NOTE: Future long-term land demands are based upon public, local, and regional land use plans for floodprone communities and portions of all counties that lie partially within the limits of the watershed. Table B36 is based upon interpretation of the potential for future development during the project life based upon published estimates of future development likely to occur in the absense of a water resource project.

farmers who plant a variety of grains and forage crops for consumption on the many dairy farms in the watershed. Nevertheless, since there is expected to be fewer farming units of larger size by the end of the planning period there is no projected net demand for additional land by this group. The most significant impact of flood management on agricultural activities within the watershed would be that potential cropland, now too wet, could be transferred from pasture into croplands. Approximately 8,300 acres of idle land could be used for agriculture if the threat of flooding could be significantly reduced. Most farmers could also benefit by reductions in costs of land preparation (i.e., ditching, contouring, and installation of drain tiles) or by a shift in the distribution of crops which would have the effect of increasing the cash flow to the agricultural sector.

B5.10 Only minimal amounts of neighborhood commercial activity are expected downstream from Reach T10. Growth in multi-family housing units is expected in the vicinity of Ransom Oaks. Development of an industrial park in the town of Amherst, adjacent to Tonawanda Creek was projected to begin in 2010. This complex, however, would be contingent upon completion of the proposed Lockport Expressway. Future commercial, industrial, and residential development in this area was assumed to comply with current Flood Insurance Administration guidelines concerning structures to be built in flood hazard areas.

B6. FLOOD DAMAGES AND MANAGEMENT BENEFITS

B6.1 The type and distribution of flood plain utilization in the watershed under existing conditions is expected to change very little between 1976 and 1980. Economic activity should increase slightly in those towns and villages adjacent to centers of growth (Buffalo, Niagara Falls, Lockport, and Batavia). However, benefits from the proposed plans of improvements would result in substantial benefits to existing and future flood plain occupants. The benefits accrue from flood inundation reduction, intensified land use within the agricultural sector, and area redevelopment benefits attributed to utilization of unemployed or underemployed labor resources in the area.

a. Flood Damage Reduction.

B6.2 The inundation reduction benefit is the value of reducing flood losses to existing and future activities which would use the flood plain without a plan of improvement. This benefit is measured by calculating the amount of reduction in flood damage and/or related costs. Related costs are those expenditures which would be voluntarily undertaken by rational individual activities to reduce flood damages and include such items as expenditures for floodproofing or elevating the building site by the use of landfill above the existing 100-year flood stages.

(1) Damage Reaches

B6.3 Flood plains along Tonawanda, Mud, Ransom, and Black Creeks were composed of 31 damage reaches. Limits of these reaches were selected based on hydrologic characteristics and land use. In this way, changes in stage or discharge at an index point of a given reach would be representative of such changes throughout the reach. The locations of the index points, brief descriptions of the damage reaches, initial damaging stages, and recurrence intervals under existing conditions are shown in Table B37. The locations of the index points, limits of the damage reaches, and the March 1960 flood are also shown on Plates B3 through B5.

(2) Damage Surveys

B6.4 Damage surveys were conducted by the Buffalo District at five separate times to determine damages caused by various floods in the Tonawanda Creek Watershed. In 1954, a thorough damage survey was carried out on the predominantly agricultural areas in the Huron Plain floodland, using the 1954 high water occurrence as a base. In 1959-1960, a damage survey was conducted in the town of Batavia in the areas flooded by the March 1942 and March 1956 floods. In 1962, the 1954 damage survey in the Huron Plain floodland was updated to reflect additional development and changes in land use that had taken place since the 1954 survey. Damages in the villages of Alexander and Attica were determined by a survey in August 1972, using the March 1960 flood as a base. In November and December 1975, a detailed damage survey was conducted in the Tonawanda Creek Watershed from the Niagara River upstream to Alexander using the Intermediate Regional Flood (IRF) as a base and considering the damage that would result from a flood of Standard Project Flood (SPF) magnitude. This latest damage survey is the basis for the existing

Table B37 - Damage Reaches

Reach No.	Location of Index Point	Damaging Elevation	Approximate Recurrence Interval in Years	Limits of Damage Reach
HURON PLAIN FLOODLAND				
	TONAWANDA CREEK VALLEY			
T-1	2.4 Stream miles from mouth	568.0	1	Stream mile 0.0 to 6.0
T-2	8.9 Stream miles from mouth	572.0	1	Stream mile 6.0 to 10.2
T-3	12.8 Stream miles from mouth	578.0	1	Stream mile 10.2 to 12.8
T-4	15.2 Stream miles from mouth	584.6	2	Stream mile 12.8 to 17.4
T-5	17.4 Stream miles from mouth	582.0	1	Stream mile 17.4 to 22.8
T-6	22.8 Stream miles from mouth	584.0	1	Stream mile 22.8 to 28.0
T-7	28.0 Stream miles from mouth	593.0	1	Stream mile 28.0 to 32.3
T-8	32.3 Stream miles from mouth	597.0	2	Stream mile 32.3 to 34.9
T-9	34.9 Stream miles from mouth	598.0	1	Stream mile 34.9 to 38.9
T-10	41.5 at Alabama gage location	616.0	1	Stream mile 38.9 to 41.5
	MUD CREEK WATERSHED			
M-1	1.6 Stream miles from mouth	580.0	1	Stream mile 0.0 to 3.5
M-2	3.5 Stream miles from mouth	583.0	2	Stream mile 3.5 to 7.0
M-3	7.0 Stream miles from mouth	590.3	4	Stream mile 7.0 to 10.8
M-4	10.8 Stream miles from mouth	596.0	2	Stream mile 10.8 to 12.3
M-5	12.5 Stream miles from mouth	596.0	1	Stream mile 12.3 to 15.0
M-6	15.1 Stream miles from mouth	603.5	2	Stream mile 15.0 to Ditch Road
	RANSOM AND BLACK CREEK WATERSHEDS			
RB-1	2.4 Stream miles from mouth	577.0	1	Stream mile 0.0 to 2.4
RB-2	4.9 Stream miles from mouth	579.0	1	Stream mile 2.4 to 4.9
RB-3	7.2 Stream miles from mouth	584.0	1	Stream mile 4.9 to 8.6
RB-4	8.6 Stream miles from mouth	586.7	2	Stream mile 8.6 to Salt Road
HOPKINS ROAD TO BATAVIA-TONAWANDA CREEK				
	TONAWANDA CREEK VALLEY - MEADVILLE ROAD TO VICINITY OF ROUTE 5			
T-11	52.5 Stream miles from mouth	847.0	3	Stream mile 41.5 to 59.5
T-12	60.3 Stream miles from mouth	876.5	3	Stream mile 59.9 to 62.8

Table B37 (Cont'd)

Reach No.	Location of Index Point	Damaging Elevation	Approximate Recurrence Interval in Years	Limits of Damage Reach
ERIE PLAIN FLOODLAND				
	CITY OF BATAVIA AND VICINITY			
B-1	Upstream Side of South Lyon Street Bridge	886.0	12	West City Limit to Walnut Street
B-2	Kibbe Park Between Elmwood and Jackson Avenues	893.2	18	Walnut Street to Lower P.C.R.R. Bridge
B-3	Kibbe Park Between Elmwood and Jackson Avenue	893.2	18	Lower P.C.R.R. Bridge to upper P.C.R.R. Bridge, right bank
B-4	Downstream side of Chestnut Street Bridge	889.0	2	Lower P.C.R.R. Bridge to southern city limit left bank
B-5	Downstream side of Chestnut Street Bridge	891.5	12	Lower P.C.R.R. Bridge to Chestnut Street, right bank
	CITY OF BATAVIA TO VILLAGE OF ALEXANDER			
T-13	65.5 Stream miles from mouth	890.4	1	Stream mile 65.4 to 77.5
	VILLAGE OF ALEXANDER			
A-1	Upstream side of Railroad Ave.	925.0	2	State Rte. 20 to 500 feet upstream from Railroad Avenue
	VILLAGE OF ATTICA			
A-2	Upstream side of Prospect St. Bridge	952.0	1	Prospect Avenue upstream to Main Street
A-3	Upstream side of Main Street Bridge	964.0	2	Main Street upstream to Dunbar Road

average annual damage estimates. Results of the 1962 damage survey for the villages of Alexander and Attica are updated to December 1975 prices. Table B38 lists the approximate number of residential, commercial and industrial, and public units that would be affected by the IRF and SPF floods. Also shown are the acreages that would be inundated by these two floods.

Table B38 - Approximate Number of Units and Acres Affected, 1975 Conditions of Development

Reach	Units Affected							
	Residential		Commercial & Industrial		Public & Other		Acres Inundated	
	SPF	IRF	SPF	IRF	SPF	IRF	SPF	IRF
T-1 through T-10	2,690	890	98	60	21	7	29,200	16,500
RB-1 through RB-4	419	386	6	5	2	2	9,850	8,770
M-1 through M-6	210	185	0	0	4	4	7,590	5,430
T-11 and T-12	213	138	24	21	1	0	7,460	6,710
B-1 through B-5	2,021	1,815	140	106	17	9	840	710
T-13	72	69	0	0	0	0	5,470	5,190
A-1 through A-3	40	8	15	10	0	0	280	250
Total	5,665	3,491	283	202	45	22	60,690	43,560

(3) Flood Damage

B6.5 Methodology

(a) Surface profiles for the IRF and SPF were used as the base for determining flood damage along Tonawanda Creek and its affected tributaries. The stage-damage relationship was established for each reach for the residential, commercial and industrial, and public and other damage categories. Damages were estimated for the Standard Project, Intermediate Regional, and lesser floods by the following method, the results of which are shown in Table B39.

B6.6 Residential

(b) The value, type of structure, and first floor elevation of each affected unit was established from field observations. The value of contents was determined based upon the estimated value of the structure. Consideration was also given to the proximity of each neighborhood to commercial development, schools and churches, the comparative appearance of each structure, and the extent of landscaping or other improvements around each

Table B39 - Estimated Damages for Floods of Various Frequencies
Total Residential Damage

Percent Chance of Occurrence	Return Interval in Years	Reach T1	Reach T2	Reach T3	Reach T4	Reach T5	Reach T6	Reach T7	Reach T8	Reach T9	Reach T10	Ransom and Black Creeks: Reaches 1-4	Mud Creek Reaches 1-6	Reach T11 Hopkins Rd. to Bushville	Reach T12 Bushville	Reach B1	Reach B2	Reach B3	Reach B4	Reach B5	Reach T13	Reach A1-A3 Alexander & Attica	Tonawanda Creek Total Damages Residential
		$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
										TOTAL RESIDENTIAL DAMAGE													
0.1	1,000	4,300,000	535,000	375,000	655,000	750,000	900,000	260,000	368,000	134,000	12,000	1,325,000	773,000	625,000	870,000	1,430,000	211,000	8,420,000	230,000	72,000	134,000	400,000	22,279,000
0.2	500	2,600,000	435,000	275,000	270,000	675,000	750,000	240,000	310,000	110,000	11,000	1,223,000	685,000	307,000	420,000	770,000	78,000	4,463,000	130,000	35,000	81,000	279,000	14,129,000
0.5	200	475,300	275,000	155,000	120,000	590,000	675,000	210,000	245,000	91,000	9,000	1,118,000	529,000	190,000	290,000	500,000	52,000	3,350,000	92,000	25,000	66,000	221,000	9,278,000
1.0	100	320,300	175,000	90,000	50,000	535,000	625,000	182,000	212,000	80,000	8,000	1,004,000	366,000	130,000	205,000	380,000	46,000	2,800,000	74,000	21,000	59,000	185,000	7,547,000
2.0	50	250,000	90,000	30,000	15,000	435,000	550,000	155,000	180,000	73,000	8,000	886,000	359,000	57,000	125,000	320,000	40,000	2,220,000	64,000	18,000	56,000	154,000	6,099,000
4.0	25	200,000	55,000	17,000	5,000	350,000	450,000	133,000	162,000	66,000	7,000	786,000	286,000	45,000	80,000	280,000	35,000	1,610,000	53,000	14,000	47,000	128,000	4,809,000
5.0	20	190,000	65,000	12,000	2,000	320,000	435,000	125,000	152,000	65,000	6,000	763,000	270,000	37,000	70,000	270,000	34,000	1,450,000	50,000	11,000	43,000	122,000	4,474,000
10.0	10	130,000	30,000	5,000	0	250,000	350,000	110,000	130,000	60,000	6,000	634,000	207,000	20,000	30,000	0	0	0	42,000	5,000	30,000	96,000	2,211,000
20.0	5	80,000	22,000	0		174,000	260,000	98,000	108,000	56,000	5,000	554,000	121,000	12,000	15,000				34,300	0	29,000	65,000	1,633,000
50.0	2	25,000	14,000			75,000	160,000	72,000	80,000	50,000	3,000	199,000	20,000	0	0				18,000		10,000	18,000	726,000
100.0	1	0	0			0	102,000	50,000	62,000	45,000	2,000	0	0						0		0	0	261,000
200.0	0.5						0	0	0	0	0												
									TOTAL COMMERCIAL AND INDUSTRIAL DAMAGE														
0.1	1,000	670,000	5,000	17,000	0	4,000	0	0	5,000	0	0	18,000	7,000	0	265,000	890,000	50,000	12,500,000	17,000	4,500,000	0	Included	18,928,000
0.2	500	105,000	4,000	17,000		3,000			3,000			17,000	3,000		125,000	640,000	5,000	6,700,000	11,000	3,130,000		in	10,765,000
0.5	200	2,000	0	17,000		2,000			2,000			17,000	3,000		50,000	235,000	0	5,000,000	8,000	2,160,000		Residential	7,496,000
1.0	100	0		16,000		1,000			1,000			16,000	1,000		25,000	130,000		4,300,000	6,000	400,000			4,896,000
2.0	50			15,000		1,000			1,000			14,000	0		12,000	80,000		2,920,000	5,000	0			3,048,000
4.0	25			14,000		0			0			12,000			10,000	40,000		0	4,000				88,000
5.0	20			14,000								12,000			9,000	30,000			3,000				68,000
10.0	10			13,000								10,000			3,000	0			2,000				28,000
20.0	5			13,000								7,000			2,000				0				22,000
50.0	2			2,000								0			0								0
100.0	1			0																			0
									TOTAL PUBLIC AND OTHER DAMAGE														
0.1	1,000	500,000	370,000	790,000	475,000	655,000	365,000	810,000	305,000	195,000	32,000	4,086,000	2,974,000	475,000	1,190,000	2,290,000	355,000	1,880,000	545,000	1,020,000	120,000	Included	19,252,000
0.2	500	300,000	295,000	390,000	320,000	355,000	260,000	610,000	215,000	145,000	22,000	3,024,000	2,118,000	450,000	670,000	1,020,000	196,000	1,150,000	95,000	330,000	81,000	in	12,046,000
0.5	200	150,000	205,000	162,000	210,000	250,000	185,000	390,000	143,000	103,000	16,000	2,026,000	1,263,000	345,000	480,000	720,000	148,000	850,000	33,000	90,000	70,000	Residential	7,839,000
1.0	100	100,000	150,000	90,000	137,000	200,000	150,000	275,000	105,000	75,000	11,000	1,366,000	640,000	220,000	390,000	530,000	125,000	700,000	23,000	23,000	62,000		5,372,000
2.0	50	50,000	100,000	60,000	65,000	130,000	110,000	205,000	75,000	50,000	8,000	796,000	351,000	205,000	280,000	360,000	90,300	500,000	15,000	15,000	54,000		3,427,000
4.0	25	0	63,000	25,000	18,000	80,000	68,000	100,000	50,000	35,000	5,000	583,000	94,000	130,000	170,000	200,000	36,000	200,000	7,000	5,000	41,000		1,910,000
5.0	20		55,000	20,000	12,000	70,000	64,000	80,000	43,000	30,000	4,000	530,000	69,000	105,000	130,000	150,000	15,000	110,000	5,000	2,000	30,000		1,532,000
10.0	10		32,000	9,000	0	50,000	40,000	55,000	27,000	21,000	3,000	414,000	20,000	15,000	0	0	0	0	2,000	0	16,000		704,000
20.0	5		9,000	0		30,000	25,000	38,000	20,000	18,000	1,000	246,000	5,000	0					0		0		392,000
50.0	2		0			11,000	7,000	18,000	10,000	15,000	1,000	13,000	0										73,000
100.0	1					0	0	0	0	9,000	0	0											9,000
200.0	0.5									0													

structure. Damages were calculated for various flood depths by use of depth-percent-damage tables for the structure and contents. The tables were developed by sampling residences of all structural types and formulating individual depth-damage curves. The curves were then averaged to establish depth-percent-damage relationships for the structure and contents of each structural type. Initial damage elevations were established as those at which sewer backup would begin or at which floodwater would begin to enter the lowest openings of structures.

B6.7 Commercial and Industrial

(c) The majority of commercial establishments include service stations, grocery stores, restaurants, motels, and automobile dealerships. The commercial damages used in this study were based on the results of previous damage surveys brought up to December 1975 prices by the application of the appropriate price indicies. A sample survey of various commercial establishments in the city of Batavia verified the updating procedure. All industrial damages were established through personal interviews. Industrial damages include damage to machinery and lost production time, inventory and wages, as well as structural damages and anticipated cleanup costs. Most industry subject to flooding is in the vicinity of Batavia.

B6.8 Public and Other

(d) Damages to public facilities such as buildings, roads, bridges, and utilities were determined based on calculated flood depths and field observations. Emergency operations and cleanup costs incurred by local, State, and Federal agencies were estimated based on actual expenditures incurred in June 1972 after the Hurricane "Agnes" flood which inundated the Upper Genesee River Basin. Generally, bridges were assumed destroyed by floods exceeding their low steel by two or more feet. Detour costs around flooded areas were based on traffic counts obtained from each county and the New York State Department of Transportation. Estimates of detour traffic flows were then used in conjunction with operating costs per mile for commercial and private vehicles to determine total detour costs for various flood events.

B6.9 Agricultural

(e) Crop damages and agricultural benefits stated in this report were predominantly updated and expanded from data originally developed for inclusion in the 1967 Flood Plain Information report for Tonawanda Creek and its tributaries. The revised data contained in this appendix includes normalized crop prices for selected crops and reflects analysis of current planting patterns in the watershed. The data is preliminary and will be refined in advanced planning stages. For this reason, stage-damage, stage-frequency, and stage-area curves are not displayed. However, a detailed conceptual framework is presented and preliminary results are tabulated in subsequent paragraphs.

(4) Stage-Damage Relationships

B6.10 The estimated damages that would be caused by the Standard Project and Intermediate Regional floods were plotted against the corresponding stages for each index point. Also, lesser flood stages and corresponding damages were calculated and plotted at each index point. The elevation of zero damage in each reach was established from data obtained from interviews and field observations. These points were then used to develop stage-damage relationships for each activity in each reach. Curves depicting these relationships are shown on Plates B9 through B39. These stage-damage curves are based on December 1975 price levels and conditions of development.

(5) Existing Average Annual Damages, Excluding Agricultural

B6.11 The stage-damage curves referenced in the previous section were used in conjunction with the stage-frequency curves (Plates A32 through A51 and A63 through A68) to determine the damage-frequency relationship for each reach. The actual calculation of existing average annual damages was done using Hydrologic Engineering Center's computer program L2510. For purposes of computing average annual damages, the Standard Project Flood was assigned a frequency of 1,000 years. The average annual damages for each reach, by activity, excluding agricultural damages, based upon December 1975 prices and development are listed in Table B40.

(6) Average Annual Damages, Agricultural

B6.12 The initial step in determining total average annual crop damage was to estimate the average annual income per acre of cropland. Average flood damage per acre was based upon a weighted distribution of crops commonly planted in the watershed and historical flood records. The procedures followed in obtaining these values are discussed in succeeding paragraphs.

B6.13 Stage-area curves were developed for each reach by relating areas of farmland flooded to various flood stages at each index point, except for Reach T-13. Sufficient data was not available to develop stage-area curves for Reach T-13. The curves were converted to stage-damage curves by multiplying areas flooded by the average damage per acre. Damage-frequency curves were developed for each index point from the stage-frequency curves and the stage-damage relationships. The area under each damage-frequency curve represents the average annual crop damage due to flooding.

B6.14 The term cropland in this report refers to land where crops are grown, cleared land that could be used to grow crops, and pastureland. The term farmland refers to all land not being utilized for residential, commercial, or public use. Farmland would include land occupied by farm buildings, wooded areas and swamp land, in addition to land designated as cropland.

B6.15 Average yields per acre in each county for specific crops were obtained from the 1969 Census of Agriculture, while normalized prices for crops grown in the flood plain were obtained from the 1975 Guideline 2, Agricultural Price Standards published by the U. S. Water Resources Council.

Table B40 - Estimated Average Annual Damages, by Reach, by Activity 1/

Reach No.	1,000-Year Return Period Residential	Commercial and Industrial	Public and Other	Total
	$	$	$	$
T-1	71,630	1,230	34,500	107,360
T-2	20,570	20	10,530	31,120
T-3	3,880	5,160	5,470	14,510
T-4	2,370	0	4,630	7,000
T-5	109,020	40	22,100	131,160
T-6	258,600	0	17,310	275,910
T-7	103,360	0	32,400	135,760
T-8	97,060	30	15,640	112,730
T-9	80,400	0	20,620	101,020
T-10	4,010	0	1,500	5,510
RB-1	75,260	0	10,610	85,870
RB-2	64,470	2,170	30,240	96,880
RB-3	101,320	0	87,760	189,080
RB-4	47,710	970	8,180	56,860
M-1	1,290	0	10,500	11,790
M-2	940	0	840	1,780
M-3	5,910	0	3,840	9,750
M-4	3,650	0	3,800	7,450
M-5	23,520	0	1,330	24,850
M-6	32,820	0	7,690	40,510
T-11	8,470	0	14,260	22,730
T-12	14,150	2,320	18,740	35,210
B-1	25,960	6,920	24,050	56,930
B-2	2,650	100	4,490	7,240
B-3	119,640	134,340	24,300	278,280
B-4	18,410	500	1,970	20,880
B-5	1,620	24,210	3,170	29,000
T-13	14,980	0	5,180	20,160
A-1	13,720	(2)	(2)	13,720
A-2	13,290	(2)	(2)	13,290
A-3	6,280	(2)	(2)	6,280
Total	1,346,960	178,010	425,650	1,950,620

1/ December 1975 Prices and Development
2/ Included in Residential

Price estimates for crops grown in the watershed but not listed in the normalized price standards were established through discussions with Agricultural Extension Service agents. A weighted average revenue per acre was established in accordance with the percent distribution of cropland in each crop category to obtain the average annual revenue per acre of cropland. The percent distribution of cropland by crop was established by examining census data by county. Discussions with Department of Agriculture personnel were necessary to refine the data base for specific areas of the watershed. Idle land was included in the distribution of total cropland but was not considered to provide a stream of income equivalent to that provided by cropped land.

B6.16 Total average annual revenue per acre of cropland was calculated to be $102.35 and the calculations are summarized in Table B41. This figure also represents the maximum damage that would be inflicted upon one acre of cropland by complete destruction of the crop by flooding. Since complete destruction of crops without recourse to a second planting of a quick growing crop to minimize losses is rarely the case, it was necessary to determine the average damage that would be inflicted by floods of various magnitudes and frequencies. Flood damages to crops are generally caused by either extended duration flooding, common in the late winter and early spring, or by high velocity and deposition flooding which is most common during the late spring or summer growing season.

B6.17 The anticipated damages from extended duration flooding for the four principal winter crops grown in the flood plains were determined from a damage duration curve which was developed from information provided by Agricultural Extension Service agents. The damage factor was expressed as a percent of the annual income from an acre of cropland whereas duration was expressed as the number of days of inundation. The average duration of flooding for each month was obtained from gage records of all high water occurrences at Meadville Road since 1922. The value obtained for each month was used with the damage duration curve to obtain average percent of crop damaged.

B6.18 The estimated damages from high velocity and deposition flooding were obtained from a curve relating crop damage to the time of year flooding occurs. This curve, adopted from the methodology developed during a flood control study on the Kansas River, was weighted to reflect the percentage of crop damage which extended duration flooding or high velocity floodwaters would cause to the six main crops grown during the summer in the flood plains. The procedure was modified slightly to allow for differences between the two watersheds in terms of regional variations in planting and harvesting time. Crop damage is expressed as a percent of the average value of the crops on an acre of cropland.

B6.19 The next step was to determine the percentage of all floods which occur during each month. This was also determined from the gage records at Meadville Road.

Table B41 - Average Annual Revenue Per Acre of Cropland

Crop	Distribution of Land by Crop	Crop Yields per Acre	Unit Price 1/	Average Annual Income Per Acre 2/	Weighted Average Value per Acre 2/
			$	$	$
Corn, Grain	15	85.9 bu.	1.89	162.35	24.35
Corn, Silage	15	14.3 t	10.20	145.85	21.88
Alphalfa	1	3.3 t	60.00	198.00	19.80
Mixed Hay	15	2.7 t	36.30	98.00	14.70
Wheat	8	40.2 bu.	2.23	89.65	7.17
Oats, Grain	8	65.4 bu.	1.06	69.30	5.54
Pasture	15	-	-	25.00	2.75
Idle Land	15	-	0.00	-	0.00
Miscellaneous	8	-	-	64.50	5.16
Total	100				102.35

1/ Unit price is based upon either 1975 Guideline 2, Agricultural Price Standards

2/ December 1975 price levels

B6.20 For each month, the larger percentage of either cause of crop damage (extended duration or high velocity) was multiplied by the total average annual revenue per acre of cropland, $102.35, and then by the percentage of all floods occurring in that month to obtain a weighted average annual flood damage per acre. The sum of weighted damages for each month determined the weighted average annual flood damage per acre of cropland. A tabulation of the data used to obtain this value, found to be $12.63, is shown in Table B42.

(a) Stage-Area Curves

B6.21 Stage-area curves were developed for each reach downstream from Meadville Road. The areas of land that would be flooded in each reach were planimetered from U. S. Geological Survey maps, scale 1:24,000, for various floods up to the IRF. The areas were reduced by 20 percent to obtain estimates of farmland. This adjustment factor is required due to rotation of acreage from cropland to fallow and also includes an estimated percentage that reflects less than 100 percent level of land utilization.

Table B42 - Average Annual Flood Damage Per Acre of Cropland

Month	Percent of Crop Damage due to 1/ Duration	Velocity	Average Annual Damage per Acre	Percent Dist. of Floods	Weighted Avg. Annual Flood Damages per Acre 2/
			$	%	$
Jan	10	7	10.24	16.0	1.64
Feb	8	6	8.19	15.2	1.24
Mar	13	7	13.31	26.4	3.51
Apr	8	7	8.19	16.8	1.38
May	8	16	16.38	7.2	1.18
Jun	-	44	45.03	2.4	1.08
Jul	-	54	55.27	1.6	.88
Aug	-	38	38.89	0.8	.31
Sep	-	18	18.42	1.6	.29
Oct	-	18	18.42	1.6	.29
Nov	4	12	12.28	3.2	.39
Dec	5	6	6.14	7.2	.44
Total				100.0	12.63

1/ The higher percentage was used in estimating average annual damage per acre.

2/ December 1975 prices.

(b) Damage-Frequency Curves

B6.22 Damage-frequency curves were developed to determine crop damages under existing cropland utilization in each of the reaches except T-13. These relationships were determined in the following manner. For any frequency of flooding, the corresponding stage was obtained from the appropriate stage-frequency curve. The area of cropland flooded at this stage was obtained by multiplying the area of farmland, flooding based upon the stage-area curves, by 54 percent, the percentage of farmland in crops. The resultant area was multiplied by $12.63, the average flood damage per acre, to obtain average annual agricultural flood damage. The area under each curve represents the average annual crop damage. A summary of average annual agricultural damages by reach is presented in Table B43 and reflects existing agricultural activity at 1975 prices.

Table B43 - Estimated Average Annual Agricultural Damages 1/

Damage Reach	Average Annual Damages
	$
T-4	980
T-5	13,470
T-6	23,370
T-7	9,480
T-8	21,130
T-9	10,110
RB-1	1,770
RB-2	5,170
RB-3	12,120
RB-4	4,780
M-1	420
M-2	1,280
M-3	3,380
M-4	840
M-5	2,560
M-6	1,820
T-13	43,700
Total	156,380

1/ December 1975 prices

(7) Average Annual Damages, Improved Conditions

B6.23 Residual average annual damages have been computed for 10 plans of improvements. Stage-frequency curves, reflecting improved conditions, were used in conjunction with the stage-damage curves to determine the damage-frequency relationship for each reach under each plan of improvement. The actual calculations of residual average annual damages and accompanying benefits, excluding agricultural, were done using HEC's computer program

Table B44 - Estimated Tangible Average Annual Damages and Benefits
December 1975 Price Levels and Conditions of Development

	Existing Average Annual Damages	Alexander Reservoir 1/ Residual Avg. Ann. Damages	Alexander Reservoir 1/ Existing Avg. Ann. Benefits	Batavia Reservoir 2/ Residual Avg. Ann. Damages	Batavia Reservoir 2/ Existing Avg. Ann. Benefits	B.R.-A.R.C. 3/ Residual Avg. Ann. Damages	B.R.-A.R.C. 3/ Existing Avg. Ann. Benefits
	$	$	$	$	$	$	$
A. Lower Tonawanda Creek*							
1. Residential	679,270	597,500	81,770	527,540	151,730	0	679,270
2. Commercial & Industrial	5,250	2,070	3,180	0	5,250	0	5,250
3. Public & Other	130,200	102,040	28,160	64,440	65,760	0	130,200
4. Agriculture	78,540	68,300	10,240	61,000	17,540	0	78,540
Subtotal	893,260	769,910	123,350	652,980	240,280	0	893,260
B. Ransom and Black Creeks							
1. Residential	288,760	208,000	80,760	140,450	148,310	0	288,760
2. Commercial & Industrial	3,140	1,700	1,440	390	2,750	0	3,140
3. Public & Other	136,790	76,160	60,630	15,500	121,290	0	136,790
4. Agriculture	23,840	17,200	6,640	11,600	12,240	0	23,840
Subtotal	452,530	303,060	149,470	167,940	284,590	0	452,530
C. Mud Creek							
1. Residential	68,130	40,620	27,510	18,780	49,350	0	68,130
2. Commercial & Industrial	0	0	0	0	0	0	0
3. Public & Other	28,000	23,170	4,830	3,960	24,040	0	28,000
4. Agriculture	10,300	6,100	4,200	2,800	7,500	0	10,300
Subtotal	106,430	69,890	36,540	25,540	80,890	0	106,430
Total - Huron Plain	1,452,220	1,142,860	309,360	846,440	605,760	0	1,452,220
D. Tonawanda Creek - Reach Between Wadeville Rd. and Batavia							
1. Residential	22,620	8,920	13,700	0	22,620	0	22,620
2. Commercial & Industrial	2,320	1,100	1,220	0	2,320	0	2,320
3. Public & Other	33,000	13,620	19,380	0	33,000	0	33,000
4. Agriculture	0	0	0	0	0	0	0
Total	57,940	23,640	34,300	0	57,940	0	57,940
E. City of Batavia							
1. Residential	168,280	64,700	103,580	0	168,280	0	168,280
2. Commercial & Industrial	166,070	104,410	61,660	0	166,070	0	166,070
3. Public & Other	57,980	30,790	27,190	0	57,980	0	57,980
4. Agriculture	0	0	0	0	0	0	0
Total	392,330	199,900	192,430	0	392,330	0	392,330
F. Batavia to Alexander (Batavia Impoundment Area)							
1. Residential	14,900	5,800	9,100	0+	0+	0+	0+
2. Commercial & Industrial	0	0	0	0	0	0	0
3. Public & Other	5,180	1,560	3,620	0	0	0	0
4. Agriculture	43,780	27,300	16,480	0	0	0	0
Total	63,860	34,660	29,200	0	0	0	0
G. Alexander							
Total	13,720	0	13,720	13,720	0	13,720	0
H. Attica							
Total Erie Plain	19,570	19,570	0	19,570	0	19,570	0
Total - Tonawanda Creek Watershed:							
1. Residential	1,275,330	965,110	330,220	720,060	560,290	33,290	1,227,060
2. Commercial & Industrial	176,780	109,280	67,500	390	176,390	0	176,780
3. Public & Other	391,150	267,340	143,810	83,900	302,070	0	385,970
4. Agriculture	156,380	118,980	37,400	75,400	37,280	0	112,680
Grand Total	1,999,640	1,420,630	579,010	879,750	1,056,030	33,290*	1,902,490

	A.R.C. 4/ Residual Avg.	A.R.C. 4/ Existing Avg.	S.R.-L.R. Residual Avg.	S.R.-L.R. Existing Avg.	D.P.M. Residual Avg.	D.P.M. Existing Avg.	S.R.-A.R.C. Residual Avg.	S.R.-A.R.C. Existing Avg.
	$	$	$	$	$	$	$	$
A. Lower Tonawanda Creek*								
1. Residential	337,350	341,920	556,620	122,650	679,270	0	150,990	528,280
2. Commercial & Industrial	1,740	3,510	480	4,770	5,250	0	0	5,250
3. Public & Other	54,580	75,620	87,960	42,240	130,200	0	11,410	118,790
4. Agriculture	39,000	39,540	63,000	15,540	78,540	0	0	78,540
Subtotal	432,670	460,590	708,060	185,200	893,260	0	162,400	730,860
B. Ransom and Black Creeks								
1. Residential	164,650	124,110	167,620	121,140	288,760	0	3,030	285,730
2. Commercial & Industrial	1,320	1,820	980	2,160	3,140	0	0	3,140
3. Public & Other	47,360	89,430	45,850	90,940	136,790	0	5,890	130,900
4. Agriculture	13,600	10,240	13,880	9,960	23,840	0	0	23,840
Subtotal	226,930	225,600	228,330	224,200	452,530	0	8,920	443,610
C. Mud Creek								
1. Residential	29,680	38,450	26,870	41,260	68,130	0	1,360	66,770
2. Commercial & Industrial	0	0	0	0	0	0	0	0
3. Public & Other	5,610	22,390	20,760	7,240	28,000	0	3,970	24,030
4. Agriculture	4,500	5,800	4,000	6,300	10,300	0	0	10,300
Subtotal	39,790	66,640	51,630	54,800	106,430	0	5,330	100,900
Total - Huron Plain	699,390	752,830	988,020	464,200	1,452,220	0	176,650	1,275,360
D. Tonawanda Creek - Reach Between Wadeville Rd. and Batavia								
1. Residential	1,990	20,630	2,260	20,360	10,270	12,350	4,660	17,960
2. Commercial & Industrial	290	2,030	230	2,090	420	1,900	420	1,900
3. Public & Other	1,440	31,560	3,300	29,700	16,620	16,380	5,840	27,160
4. Agriculture	0	0	0	0	0	0	0	0
Total	3,720	54,220	5,790	52,150	27,310	30,630	10,920	47,020
E. City of Batavia								
1. Residential	2,680	165,600	16,780	151,500	58,660	109,620	32,290	135,990
2. Commercial & Industrial	0	166,070	16,570	149,500	50,210	115,860	35,460	130,610
3. Public & Other	0	57,980	5,760	52,220	26,780	31,200	11,680	46,300
4. Agriculture	0	0	0	0	0	0	0	0
Total	2,680	389,650	39,110	353,220	135,650	256,680	79,430	312,900
F. Batavia to Alexander (Batavia Impoundment Area)								
1. Residential	5,800	9,100	0	14,900	14,900	0	0	14,900
2. Commercial & Industrial	0	0	0	0	0	0	0	0
3. Public & Other	1,560	3,620	0	5,180	0	0	0	5,180
4. Agriculture	27,300	16,480	0	43,780	43,780	0	10,000	33,780
Total	34,660	29,200	0	63,860	63,860	0	10,000	63,860
G. Alexander								
Total	0	13,720	0	13,720	13,720	0	0	13,720
H. Attica								
Total Erie Plain	19,570	0	0	19,570	19,570	0	0	19,570
Total - Tonawanda Creek Watershed:								
1. Residential	561,720	713,610	770,150	505,180	1,153,360	121,970	192,340	1,082,790
2. Commercial & Industrial	3,350	173,430	18,260	158,520	59,020	117,760	35,880	140,900
3. Public & Other	110,550	280,600	163,630	227,580	343,570	47,580	38,710	352,440
4. Agriculture	84,400	71,980	80,880	75,580	156,380	0	10,000	146,380
Grand Total	760,020	1,239,620	1,032,960	966,700	1,712,330	287,310	277,130	1,722,510

* Damages for Reach T-1 on Tonawanda Creek have not been included in the damage analysis. No protection can be provided because this reach would be subject to flooding from Ellicott Creek, the major tributary of Tonawanda Creek.

\+ Since the activities in this reach subject to damage would be purchased, average annual damages and benefits are not included in the alternatives with the Batavia Reservoir.

1/ Maximum release of 2,000 cfs, natural release at L.V.R.R., no storage downstream of Batavia.
2/ Maximum release of 3,000 cfs at L.V.R.R., no storage downstream of Batavia, Standard Project Flood Design.
3/ Maximum release of 3,000 cfs at L.V.R.R., Alabama Reservoir Compound, Standard Project Flood Design.
4/ Maximum release of 2,000 cfs from upper reservoir, natural release from lower reservoir to 6,000 cfs, hold 6,000 cfs, no storage downstream of Batavia.

L2510. Average annual residual damages and accompanying benefits, based on a 1,000-year return period for a Standard Project Flood and December 1975 price levels and conditions of development are shown in Table B44.

B6.24 A benefit-cost ratio for each flood damage management plan based upon December 1975 conditions of development was developed from the data in Tables B39 through B44, and are summarized in Table B45. A comparison of the benefits and costs for existing conditions are presented below.

Table B45 - Benefit-Cost Ratios for Existing Conditions 1/

Plan	Average Annual Benefits 2/	Average Annual Costs	Benefit-Cost Ratio
	$	$	
S.R.-L.R. Plan	966,700	2,983,900	0.32
S.R.-A.R.C. Plan	1,722,500	3,193,300	0.54
Alexander Reservoir	579,000	695,000	0.83
B.R.C. Plan	1,239,600	1,332,000	0.93
Batavia Reservoir	1,056,000	1,848,700	0.57
B.R.-A.R.C. Plan	1,902,500	2,836,500	0.67
B.P.M.	287,300	130,000	2.21

1/ December 1975 prices.
2/ Benefits based upon Table B44.

B6.25 A plan for local protection at Batavia was the only structural flood management plan justified based upon existing conditions. However, this plan protects only a small portion of the city of Batavia and does not contribute towards satisfying regional flood damage management needs in the watershed to the extent of the other plans. Therefore, future benefits for all plans of improvement were evaluated.

B6.26 Future benefits include the impact of rising regional per capita income on the existing stock of residential contents in the floodplain (affluence factor benefits), discounted value of future flood damages to units which would locate in the floodplain without a flood damage management plan (future development benefits), reduction in development costs which would accrue to future floodplain occupants (landfill and floodproofing savings), increased utilization of land within the agricultural sector (intensification benefits), and beneficial impact of construction activity upon the area's economy if a flood damage management project were built (area redevelopment benefits).

b. <u>Future Benefits</u>.

(1) Flood Damages to Future Development

B6.27 Future undiscounted average annual flood damages were projected to rise from existing levels anticipated to occur in 1980 based upon the extent of additional development expected to locate in the floodplain under without-project conditions and the susceptibility of these units to floods in excess of an Intermediate Regional Flood. The assumed enforcement of Flood Insurance Administration regulations for minimum elevations of lowest openings for new construction or substantial improvements to existing units was the basis for projecting future undiscounted average annual flood damages. Although FIA regulations are effective in substantially reducing flood damages for floods below the IRF flood stage, they will not appreciably reduce SPF unit flood damages. Average annual unit flood damages on an undeferred basis that would result from additional development in the residential and industrial and commercial sectors was estimated based upon the assumption that future units would be similar to existing development.

B6.28 This figure was based upon the total estimated damages for each flood greater than the IRF multiplied by its respective probability of occurrence. A weighted average annual damage figure was then divided by the number of residential or commercial units estimated to be within each flooded area outline. The result was an average annual damage per unit figure of $30.00 which was considered to be representative of the entire watershed.

B6.29 Table B36 provided an estimate of future acreage which is the basis for projecting undiscounted average annual flood damages. At the end of year 2030, an additional 1,800 acres of residential, 75 acres of commercial and 125 acres of industrial lands are expected to develop. Average number of units multiplied by estimated average annual flood damages per unit of $30.00 resulted in an increase in <u>existing</u> average annual flood damages from $1,999,640 to $2,171,140. The undiscounted increase of $171,500 ($162,000 for residential and $9,500 for the commercial and industrial units) is equivalent to $48,500 on a discounted average annual basis.

B6.30 A plan of improvement that would provide about Standard Project Flood Protection would eliminate this future increase in average annual flood damages. The BR-ARC Plan would have the effect of preventing not only the $1,902,500 average annual damages for existing development but would also prevent the additional $48,500 average annual damages attributed to future development in the watershed. The remaining plans of improvement provide lesser degrees of protection due to lower design levels. Undiscounted and discounted average annual equivalent flood damages and residual flood damages for the various plans are included in Table B46. Estimates of future average annual damages do not include public and other damages that would result from future inundation of a greater number of roads, bridges or higher detour costs associated with a greater number of floodplain residents. The discounted average annual equivalent of $48,500 is therefore a conservative estimate of future average annual flood damages that would result from future development in the watershed. Additional refinements to future flood damages, especially in the public and other sector, will be made in subsequent planning stages.

Table B46 - Future Residual Damages and Benefits (Without Affluence) 1/ 3/ 5/

Plans	1975 4/ Residual Avg. Annual Damages	1975 4/ Avg. Annual Benefits	1980 4/ Residual Avg. Annual Damages	1980 4/ Avg. Annual Benefits	1990 Residual Avg. Annual Damages	1990 Avg. Annual Benefits	2000 Residual Avg. Annual Damages	2000 Avg. Annual Benefits
	$	$	$	$	$	$	$	$
Alexander Reservoir	1,420,630	579,010	1,420,630	579,010	1,426,230	584,610	1,431,830	590,210
Batavia Reservoir Plan	879,750	1,056,030	879,750	1,056,030	890,950	1,067,230	902,150	1,078,430
B.R.-A.R.C. Plan	33,290	1,902,500	33,290	1,902,500	33,290	1,936,100	33,290	1,969,700
B.R.C. Plan	760,020	1,239,620	760,020	1,239,620	776,820	1,256,400	793,620	1,273,200
S.R.-L.R. Plan	1,032,940	966,700	1,032,940	966,700	1,044,140	977,900	1,055,340	989,100
Batavia Project Modification	1,712,330	287,310	1,712,330	287,310	1,745,930	287,310	1,779,930	287,310
S.R.-A.R.C. Plan	277,130	1,722,510	277,130	1,722,510	293,930	1,739,310	310,730	1,756,110
Nonstructural Base Plan	1,297,240	702,400	1,297,240	702,400	1,330,840	702,400	1,364,440	702,400

Plans	2010 Residual Avg. Annual Damages	2010 Avg. Annual Benefits	2020 Residual Avg. Annual Damages	2020 Avg. Annual Benefits	2030 Residual Avg. Annual Damages	2030 Avg. Annual Benefits	Discounted Avg. Annual Residual Damages 1/ 2/	Discounted Avg. Annual Benefits 1/ 2/
	$	$	$	$	$	$	$	$
Alexander Reservoir	1,437,430	595,810	1,443,190	601,570	1,449,190	607,570	1,461,050	587,090
Batavia Reservoir Plan	913,350	1,089,630	924,850	1,101,130	936,850	1,113,130	912,080	1,072,200
B.R.-A.R.C. Plan	33,290	2,003,300	33,290	2,037,900	33,290	2,074,000	33,290	1,950,990
B.R.C. Plan	810,420	1,290,000	827,720	1,307,300	845,770	1,325,350	784,270	1,263,840
S.R.-L.R. Plan	1,066,540	1,000,300	1,078,040	1,011,800	1,090,040	1,023,800	1,065,270	982,870
Batavia Project Modification	1,813,530	287,310	1,848,130	287,310	1,884,230	287,310	1,760,830	287,310
S.R.-A.R.C. Plan	327,510	1,772,910	344,830	1,790,210	362,880	1,808,260	301,380	1,746,750
Nonstructural Base Plan	1,398,040	702,400	1,432,640	702,400	1,468,740	702,400	1,345,740	702,400

1/ 1975 Prices.
2/ Future damages and benefits discounted for 50 years normal growth from 1980, 100-year project life, and 6.125 percent interest rate.
3/ Future increases in undiscounted average annual flood damages are based on a normal growth response curve for residential, commercial, and industrial sectors only. Public and other or agricultural damages or benefits were not evaluated.
4/ Development in period 1975 to 1980 occurs outside IRF outline. After 1980, future development follows pattern of Table B36.
5/ Batavia Project Modification is unable to protect future flood plain development downstream of Reach T10, while an NBP assumes future units comply with Flood Insurance Administration's minimum low opening restrictions.

(2) Affluence Factor Benefit

B6.31 The affluence factor benefit is the increase in the average annual residential flood reduction benefits attributed to the effect of increasing regional per capita income on the constant dollar value of real property and contents in the floodplain. The extent of this benefit is determined by the existing relationship between the estimated value of contents and value of residential structures in the floodplain and the rate of growth in regional per capita income.

B6.32 The dollar value of residential contents was projected into the future at an annual growth rate equal to the annual rate of change in regional per capita income. Growth in residential contents was terminated when the total stock of residential contents in the future equaled 75 percent of the value of residential structures, a criteria imposed upon the methodology by current Corps procedural guidelines. Residential contents beyond this point were held constant at this upper limit for the remainder of the planning period.

B6.33 Per capita income projections are the basis for this growth and these statistical series were based upon <u>OBERS 1972 Series E Population Projections</u>, Volume 5. Residential contents, when projected from existing levels in 1976 at an annual rate of increase equal to that of regional per capita income, reach their upper limit of 75 percent of the value of residential structures approximately in the year 2010.

B6.34 The impact of the affluence factor on average annual benefits is directly related to the proportion of residential damage to total flood damages and to the distribution of total residential damages between the content and the structure subtotals.

B6.35 If a high proportion of total flood damages under existing conditions are attributed to protection of a large suburban area, affluence factor benefits will be relatively large. However, if a commercial or industrial area is the primary recipient of flood damage reduction, the affluence factor benefits will be relatively large. However, if a commercial or industrial area is the primary recipient of flood damage reduction the affluence factor benefits, which are usually limited to the residential sector, may be negligible or nonexistent.

B6.36 When a high percentage of total residential damage results from damages to contents, which might occur as a result of sewer backup or basement flooding, then affluence factor benefits will be great. Little or no content damages within the residential sector would produce negligible or no affluence factor benefits. A summary of the affluence factor benefits attributed to the various plans are included in Table B47.

c. <u>Reduction in Related Costs</u>.

B6.37 Floodproofing costs that would be incurred without a project which could be avoided as the result of implementation of a plan of improvement were considered a benefit to the project. Floodproofing costs were considered to include all expenditures to eliminate or reduce flood damages to

Table B47 - Undiscounted Average Annual Flood Damage Reduction Benefits Including Affluence Factor and Future Development 1/ 4/

Plan	Existing Conditions 1975	Future Conditions 2/ 1980	1990	2000	2010	2020	2030	Discounted Avg. Annual Benefits With Affluence	Discounted Avg. Annual Affluence Factor Benefits 3/
	$	$	$	$	$	$	$	$	$
B.R.-A.R.C. Plan	1,902,500	1,965,710	2,059,330	2,154,510	2,208,170	2,242,770	2,278,870	2,087,120	136,130
S.R.-A.R.C. Plan	1,722,510	1,778,290	1,848,050	1,919,190	1,953,690	1,970,990	1,989,040	1,866,900	120,150
B.R.C. Plan	1,239,620	1,276,360	1,328,060	1,380,670	1,409,140	1,426,440	1,444,490	1,343,010	79,170
Batavia Reservoir Plan	1,056,030	1,083,860	1,121,490	1,159,810	1,179,840	1,191,340	1,202,340	1,132,030	60,000
S.R.-L.R. Plan	966,700	992,720	1,028,630	1,065,180	1,084,640	1,096,140	1,108,140	1,038,910	56,040
Alexander Reservoir	579,010	596,030	617,790	639,960	650,960	656,720	662,720	623,740	36,650
Batavia Project Modification	287,310	293,590	305,840	324,210	344,570	344,570	344,750	313,580	26,270
Nonstructural Base Plan	702,400	725,450	770,430	837,890	912,670	912,670	912,670	798,890	73,440

1/ 1975 price levels and future conditions of development.
2/ Based upon future development anticipated to occur without a flood management project.
3/ Discounted average annual affluence factor benefits equal to discounted average annual benefits with affluence minus discounted average annual benefits without affluence in Table B46.
4/ Data in Table B47 is based upon Table B46 adjusted for growth in benefits due to affluence.

structures and/or their contents. Expenditures for floodproofing are usually for structural measures designed to prevent floodwater from entering buildings, or for landfilling to elevate the low openings of buildings above the 100-year flood surface. Occasionally the practice for elevating buildings on stilts or pilings protects them against flooding. Floodproofing costs are usually related to the design, construction materials, and intended function of a building. For example, residential buildings are not commonly flood-proofed because the construction materials used and techniques employed are not able to withstand significant hydraulic loading imposed by floodwaters. Therefore, the most common method employed is landfilling residential building sites to appropriate elevations.

(1) Landfill Savings

B6.38 Landfill savings were defined as the difference between the cost of landfill required without versus with each of the proposed projects. Under existing Flood Insurance Administration regulations, new buildings and substantial improvements to existing buildings must be floodproofed against the 100-year flood. Elevation of building sites is the most common means of floodproofing residential properties. The larger site sizes of commercial and industrial activities often makes landfilling too costly. Therefore, other floodproofing means such methods as flood shields are commonly used. The effectiveness of these methods can be enhanced by including them into the design criteria and wise choice of construction materials for these buildings. Some minimum amount of landfill is frequently utilized for sites fo industrial and commercial activities to achieve proper drainage. Each acre of projected commercial and industrial land use demand in the floodplains was assumed to be landfilled in the vicinity of the structure to 1.5 feet above the existing ground elevation with or without a plan of improvement.

B6.39 There is a significant variation in 100-year flood stages between reaches of the main channel and Mud, Ransom and Black Creeks. Preliminary hydraulic data indicates that, without a project, future development in the Huron Plain must landfill their building sites to an average height of four feet to obtain protection against an Intermediate Regional flood. Those plans of improvement which incorporate the considered Alabama Reservoir Compound would be able to significantly reduce flood stages in downstream area where future development under without project conditions is anticipated to occur.

B6.40 Projections of future development by activity and reach within the floodplain (Table B36) were used as the basis for the quantification of future landfill cost avoided for future residential structures and was also the basis for floodproofing costs avoided in the commercial and public and other sectors. The extent of such development was then used in conjunction with the amount of reduction in flood stages by reach to calculate total landfill cost avoided by the residential sector.

B6.41 Although it requires 1,613 cubic yards of landfill to cover a vacant acre of land to a depth of one foot, most building lots were assumed to be filled to the 100-year flood elevation only in the immediate vicinity

of the structures. One acre, 43,560 square feet, filled to a depth of one foot requires 43,560 cubic feet; this amount was then divided by 27, or the number of cubic feet in one cubic yard, to arrive at the equivalent number of cubic yards of landfill required to raise one acre one foot. The remaining area of the building lot would then be filled to a gradually decreasing elevation in order to achieve the required drainage of surface water away from the structure. Therefore, it was estimated that a lesser amount, or approximately 80 percent (1,290 cubic yards) would be needed per residential acre since roads, sidewalks and driveways would probably be constructed at the existing or natural elevation. Therefore, 1,290 cubic yards was assumed to be equivalent to raising one residential acre one foot and was used as the basis for calculations of future landfill costs avoided.

B6.42 Implementation of any plan which could reduce downstream flood stages would result in substantial future landfill cost savings. A significant amount of future residential development is anticipated to occur in Reaches T-1 and T-2 in the town of Amherst but was not considered in the benefit calculation since the channel capacity downstream of the New York State Barge Canal is sufficient to carry the 100-year discharge. This development was also not considered in determining the total projected land use demand presented in Table B36. Table B48 presents the maximum landfill reduction which is associated with the Batavia Reservoir - Alabama Reservoir Compound plans. The landfill reduction benefits associated with other plans of improvement are based upon the hydrological effectiveness of the alternate plans relative to the SR-ARC and BR-ARC schemes. A summary of the landfill savings attributed to the various plans are presented in Table B52.

(2) Floodproofing Savings

B6.43 Floodproofing savings are cost reductions produced by any flood control project that would reduce the susceptibility of future commercial or industrial structures to flooding. Total future floodproofing costs are dependent upon the number of structures which will be built in the floodplains. Floodproofing savings were estimated using an average commercial structure density of two units per acre. Actual commercial land utilization will depend on site locations, types of commercial activity, and relative values of land to be occupied by commercial units. Average costs for floodproofing commercial and industrial units are much higher than those for residential structures. In most cases, industrial and commercial floodproofing techniques are more extensive and must project equipment and inventory of much greater value than residential contents. The only site for future industrial development in the floodplain is in the town of Amherst at the proposed intersection of the Lockport Expressway and the Buffalo Outer Belt Highway in northcentral Amherst (Reach T2) downstream from the confluence of the Barge Canal and Tonawanda Creek. Industrial development in this area should not be affected by the 100-year discharge of Tonawanda Creek, therefore, floodproofing costs avoided were not evaluated for the industrial sector. An estimated average structural expenditure of $5,000 per commercial unit was utilized in Table B49 to estimate the present value of future floodproofing costs avoided for commercial activity which can be expected in the future. This figure was selected as the average floodproofing cost per unit necessary to obtain protection from an

Table B48 - Average Annual Residential Landfill Savings 1/

	1980-90	1990-2000	2000-10	2010-20	2020-30
	$	$	$	$	$
Increase in Residential Land Use Demand (acres) 2/	75	150	250	425	750
Adjustment Factor 3/	0.65	0.65	0.65	0.65	0.65
Net Residential Land Use Demand (in acres)	48.75	97.50	162.50	276.25	487.5
Average Acres per Year	4.875	9.750	16.25	27.625	48.75
Fill Cost to Raise Future Residential Units Four Feet 4/	20,740	20,740	20,740	20,740	20,740
Annual Landfill Savings for the Period 5/	100,100	202,200	337,000	572,900	1,011,100
Present Worth of $1 Per Period	N/A	14.81	13.58	11.35	7.32
Present Value Factor	N/A	.5519	.3045	.1681	.0927
Amortization Factor 6/	N/A	.0614	.0614	.0614	.0614
Discounted Avg. Annual Savings 5/	101,100	101,500	85,600	67,100	42,100
Total Avg. Annual Residential Landfill Savings					397,400

1/ Calculations pertain to the S.R.-A.R.C. and B.R.-A.R.C. Plans only.
2/ Incremental land demand is based on Table B36.
3/ If 90 percent of projected residential land develops and 90 percent of this acreage is actually suitable for construction sites and 20 percent is required for auxiliary uses (roads, sewers, sidewalks, rights-of-way, etc.) the adjustment factor is .9 X .9 X .8 or 0.65.
4/ Cost of first acre-foot of landfill was estimated at $1,390 due to material available from excavation of basement and foundations. Cost of each successive acre-foot is 1,290 cu. yds. X $5.00 or $6,450. $1,390 + (3 X 6,450) = $20,740.
5/ Rounded to nearest hundred.
6/ 100-year economic life at 6-1/8 percent project interest rate.

N/A - Not applicable.

Table B49 - Average Annual Floodproofing Savings 1/

Time Period	Increase in: Number of Commercial Units 2/	Undiscounted Incremental Savings 3/	Average Annual Equivalence Factor	Present Worth of $1 Per Period	Present Worth Factor	Amortization Factor 4/	Discounted Avg. Annual Floodproofing Savings
							$
1980-1990	10	50,000	.7758	N/A	N/A	N/A	38,790
1990-2000	20	100,000	.7754	14.36	.5390	.0614	36,850
2000-2010	30	150,000	.7745	13.23	.2905	.0614	27,400
2010-2020	40	200,000	.7729	11.12	.1566	.0614	16,530
2020-2030	50	250,000	.7699	7.23	.0844	.0614	7,210
Total							126,780

1/ Batavia Reservoir Compound and Alabama Reservoir Compound Plan Only.
2/ Refer to Table B36 for acreage estimates. Costs based upon two commercial units per acre.
3/ Floodproofing expenditure estimated at $5,000 per unit.
4/ Economic life of 100 years; Project interest rate of 6-1/8 percent

N/A - Not applicable to calculation

Intermediate Regional flood under existing conditions. The elimination of all or a portion of these costs were considered a benefit to any plan of improvement. Average annual floodproofing costs avoided are greatest for the Batavia Reservoir-Alabama Reservoir Compound and the Sierks Reservoir-Alabama Reservoir Compound plans. These schemes provide substantial protection for occupants of the Huron and Erie floodplains. There is no floodproofing costs avoided benefit for the Batavia Project Modification or the Non-Structural Base Plan.

B6.44 The benefit of future floodproofing costs avoided is considerable for any plan which incorporates the Alabama Reservoir Compound since most future commercial development is expected to locate in the Huron Plain floodlands. This downstream impoundment would provide a significant reduction in flood stages in all reaches in the Huron Plain. Benefits associated with the other plans of improvement were estimated based upon their hydraulic and hydrologic effectiveness relative to the flood protection provided by the Batavia Reservoir Compound and Alabama Reservoir Compound.

d. Agricultural Intensification.

B6.45 This benefit is the value to activities that can utilize land more intensively because of a flood management project. The protection and the extent of areas protected vary between each plan of improvement. The maximum intensification benefit would accrue to the Batavia Reservoir-Alabama Reservoir Compound Scheme.

B6.46 The inventory of land use in Table B35 shows that approximately 8,300 acres of farmland is classified as inactive agricultural land. This land was recently removed from active agriculture but is not yet committed to forest regeneration. A reduction of the existing flood hazard would induce farm operators to either put more of their idle cropland into production or to utilize their existing crop acreage more intensively. Higher utilization of existing cropland could be achieved by planting higher value crops, such as vegetables. This benefit was determined by use of the 1969 Census of Agriulture and the following methodology.

B6.47 For all plans of improvement except the Batavia Reservoir Plan, all idle acreage was assumed to become fully utilized by the end of a 10-year growth period and remain productive over the remaining project life. Net profits for each additional acre which could be farmed were estimated at $65. This represents the average net profit per cropped acre in Genesee County in 1969, updated to 1975 price levels based upon the 63 percent increase in the wholesale price index for farm products for this period. The Batavia Reservoir Plan would actually reduce the total amount of active agricultural land in Reach T13. This reservoir would encumber economic activity on up to 6,460 acres that could be occupied by flood waters during flooding.

B6.48 Other farm operators who would not be induced to inrease their acreage by utilization of idle lands may intensify their activities by shifting their existing crop distribution toward higher value crops. As a result many farmers would benefit from a project as a result of greater cash flows attributed to either higher value crops or to lower farm expenses directly attributable to a Corps project.

B6.49 Preparation of cropland susceptible to deposition from floodwaters commonly involves removal of debris and/or extra fertilization and tilling prior to cultivation. Artificial drainage projects including installation of tile drains and construction of surface ditches to allow floodwaters to drain from the land, now important for viable floodplain agriculture in the watershed, would not be needed. The intensification benefit in this case was measured as the increase in net farm revenue per acre.

B6.50 Current profits of $65 per acre were estimated to increase (as a result of a flood damage management project) 12.5 percent to $73 per acre over a 10-year growth period. This increase in net profits per acre would begin in the base year (1980), reach a maximum 10 years later and continue at this level over the remaining project life. Future average annual increased revenues were converted to current dollars and amortized over the project life. Most farmland which would benefit from intensified agricultural outputs is located in the Huron Plain. The plans for flood management which would cause the greatest reduction in flood stages and intensification benefits are the Batavia Reservoir-Alabama Reservoir Compund and the Sierks Reservoir-Alabama Reservoir Compound schemes. The remaining plans which provide lesser degrees of protection also result in lower agricultural intensification benefits.

e. Area Redevelopment.

B6.51 Area redevelopment benefits are the beneficial effects from the utilization of unemployed or underemployed labor resources directly in the construction of a project. This type of benefit is only applicable in areas determined by the U. S. Department of Labor to have substantial or persistent unemployment, i.e., an unemployment rate of six percent or more. The city of Buffalo, which has been on this list since May 1974, currently has an unemployment rate of 14.2 percent. Since unemployed labor resources in the Buffalo urban area are within reasonable commuting distances from the sites of any proposed project, and since the Buffalo metropolitan area is currently classified as an area of substantial unemployment, redevelopment benefits were evaluated and project benefits were increased by corresponding amounts.

B6.52 Total direct construction costs (see Table B50) exclude engineering, design, supervision and administration costs. Labor costs were estimated to be 40 percent of total direct construction costs. Labor skills needed for project construction would be concentrated in the skilled trades. Heavy equipment operators would comprise most of the skilled labor component, although smaller numbers of carpenters, cement finishers and other skilled workers would be needed.

B6.53 There were slightly more than 5,200 unemployed construction workers receiving unemployment benefits in the Buffalo SMSA during January 1976, or 17 percent of total unemployed labor resources in the area. The total of unemployed construction workers in the Rochester area for the same month was placed at 1,200. These figures are conservative since unemployment beneficiary data does not include labor resources which have exhausted their unemployment benefits. Total wages paid to local labor resources an estimated to be 75 percent of the total direct labor component. Locally

unemployed or underemployed labor resources were assumed to receive 75 percent of all wages paid to local labor. Average annual area redevelopment benefits were determined for each plan of improvement and are included in Table B50 and summarized in B52.

Table B50 - Summary of Total Direct Construction Costs

	Construction Cost [1]	Estimated Labor Costs	Wages for Unemployed Labor Resources	Estimated Average Annual Area Redevelopment Benefits
	$	$	$	$
Non-Structural Base Plan	12,795,900	5,118,400	2,879,100	176,800
Sierks Reservoir - Linden Reservoir Plan	34,376,500	13,750,600	7,734,700	474,900
Sierks Reservoir - Alabama Reservoir Compound Plan	37,995,100	15,198,000	8,548,900	524,900
Alexander Reservoir Plan	8,098,600	3,239,400	1,822,200	111,900
Batavia Reservoir - Compound Plan	13,589,300	5,435,700	3,057,600	187,700
Batavia Reservoir Plan	15,772,600	6,309,000	3,548,800	217,900
Batavia Reservoir - Alabama Reservoir Compound Plan	27,387,900	10,955,200	6,162,300	378,400
Batavia Project Modification Plan	1,150,600	460,200	258,900	15,900

1/ Excluding engineering, design, supervision, administration and property costs.

f. <u>Standard Project Flooding with the Selected Plan.</u>

B6.54 Stage-frequency curves for all reaches in the Tonawanda Creek Watershed (plates A32 through A51 and A63 through A68 in Appendix A) present the extent of stage reduction for various flood frequencies. The Standard Project flood was assigned a 1000-year return period for the damage analysis. The difference in duration and stages between existing and improved conditions for those reaches downstreeam of the Tonawanda Indian Reservation are slight due to the effects of local inflows.

B6.55 Future residential development anticipated to occur within the watershed downstream of Reach T-10 is expected to consist of individually

Table B51 - Standard Project Flood Damages

Reach	Residential		Commercial and Industrial		Public and Other	
	Existing [1/] Conditions	Improved [3/] Conditions	Existing [1/] Conditions	Improved [3/] Conditions	Existing [1/] Conditions	Improved [3/] Conditions
T1	4,300,000	4,300,000	670,000	670,000	500,000	500,000
T2	535,000	510,000	5,000	5,000	370,000	350,000
T3	375,000	340,000	17,000	20,000	790,000	580,000
T4	455,000	420,000	0	0	475,000	435,000
T5	750,000	725,000	4,000	6,000	455,000	425,000
T6	800,000	770,000	0	0	365,000	300,000
T7	260,000	255,000	0	0	810,000	760,000
T8	368,000	355,000	5,000	5,000	305,000	288,000
T9	134,000	125,000	0	0	195,000	183,000
T10	12,000	11,700	0	0	32,000	29,000
RB1 thru RB4	1,325,000	1,269,000	18,000	18,000	4,086,000	3,484,000
M1 thru M6	773,000	744,000	7,000	8,000	2,974,000	2,445,000
T11	425,000	20,000	0	0	475,000	15,000
T12	870,000	40,000	245,000	10,000	1,190,000	40,000

Table B51 - Standard Project Flood Damages (Cont'd)

Reach	Residential		Commercial and Industrial		Public and Other	
	Existing 1/ Conditions	Improved 3/ Conditions	Existing 1/ Conditions	Improved 3/ Conditions	Existing 1/ Conditions	Improved 3/ Conditions
B1	1,430,000	0	890,000	0	2,290,000	0
B2	211,000	0	50,000	0	355,000	0
B3	8,420,000	0	12,500,000	0	1,880,000	0
B4	230,000	45,000	17,000	0	565,000	5,000
B5	72,000	0	4,500,000	0	1,020,000	0
T13	134,000	134,000	0	0	120,000	120,000
A1-A3	400,000	400,000	2/	0	2/	0
	22,279,000	10,463,000	18,928,000	742,000	19,252,000	9,959,000

1/ Table B40
2/ Included in Residential
3/ Residual Damages After Implementation of the Batavia Reservoir Compound

sited homes on landfilled building sites. This type of construction would be similar to the type of homes now in this area. Future development of this type would have an insignificant effect upon future SPF flood stages. In contrast, residential subdivisions situated on large tracts of land which are completely landfilled above the 100-year flood stages would result in higher future flood stages. However, this type of residential development has a very low probability of occurring over extensive areas in the Huron Plain Floodland.

B6.56 Implementation of the Selected Plan would have as its most beneficial impact the complete reduction of overbank flooding by SPF floodwaters in Reaches B1, B2, B3 and B5. Only Reach B4 has any residual damages due to SP flooding - approximately $50,000 under improved versus $812,000 under existing conditions. Protection of commercial and industrial activity in the city of Batavia from SPF flooding eliminates more than 90 percent of total commercial and industrial damages in the watershed attributed to this rare flood event. Table B51 indicates the reduction in SPF flood damages by reach after implementation of the Selected Plan.

g. Total Benefits and Economic Efficiency.

(1) National Economic Development

B6.57 Flood related planning policy should consider all practicable and relevant alternatives applicable to sound floodplain management. Alternatives can include measures to modify floods and measures to modify damage susceptibility. Floodplain management, including flood control and prevention, can contribute to National Economic Development (NED) by improving the net productivity of floodprone land resources. This can result in either an increase in output of goods and services and/or reduction of the cost of using the land resources. NED benefits are categorized according to their effect as inundation reduction, intensification or location benefits. Inundation reduction (existing and future) and intensification benefits were evaluated for various flood control plans in the Tonawanda Creek Watershed. Location benefits were not evaluated since land use pattern in the floodplain areas would not be changed to new economic uses as a result of the project.

B6.58 Flood control programs contribute to national economic development by reducing or eliminating flood damages or reducing the limitations on uses of specified land resources. Flood damage management within the Tonawanda Creek Watershed could be provided by various structural and nonstructural plans. These plans range from floodproofing of affected residences to structural measures which control floodwaters.

(2) Summary of Average Annual Benefits

B6.59 A summary of average annual benefits for the considered plans of improvement are presented in Table B52. Flood damage reduction benefits attributed to the Selected Plan are estimated at $1,343,000 and consist of benefits for existing development ($1,239,600), future development $24,200) and the affluence factor ($79,200). Development cost savings ($200,800), agricultural intensification ($216,500) and area redevelopment benefits

Table B52 - Summary of Average Annual Benefits 1/ 2/

	B.R. - A.R.C.	S.R. - A.R.C.	B.R.C.	Batavia Reservoir	S.R. - L.R.	Alexander Reservoir	B.P.M.	Non-Structural Base Plan
	$	$	$	$	$	$	$	$
1. Total Flood Damage Reduction	2,087,100	1,866,900	1,343,000	1,132,000	1,038,900	623,000	313,600	775,800
a. Existing Development	1,902,500	1,722,500	1,239,600	1,056,000	966,700	579,000	287,300	702,400
b. Future Development	48,500	24,200	24,200	16,200	16,200	8,100	0	0
c. Affluence Factor	136,100	120,200	79,200	59,800	56,000	36,700	26,300	73,400
2. Savings to Future Development	524,200	524,200	200,800	272,800	200,800	136,000	0	0
a. Floodproofing Savings	126,800	126,800	44,400	63,400	44,400	31,700	0	0
b. Landfill Savings	397,400	397,400	156,400	209,300	156,400	104,300	0	0
3. Agricultural Intensification	376,000	367,700	216,500	204,100	18,600	12,400	0	0
4. Area Redevelopment	378,400	524,900	187,700	217,900	474,900	111,900	15,900	176,800
TOTAL AVERAGE ANNUAL BENEFITS	3,365,700	3,283,700	1,948,000	1,826,700	1,733,200	884,100	329,500	952,600

1/ 1975 Price levels and 1980 Conditions of Development

2/ Rounded to the nearest hundred dollars

($187,700), when added to the flood damage reduction benefits results in total average annual benefits of $1,948,000.

(3) Economic Efficiency and the Selected Plan

B6.60 Protection for the city of Batavia can be provided by various structural measures located upstream of this city. Four of these plans provide approximately the same magnitude of damage reduction in Batavia on an average annual basis. These plans and their average anuual flood reduction benefits in Batavia are the Batavia Reservoir ($392,330), BR-ARC ($392,330), the Batavia Reservoir Compound ($389,650) and the SR-LR ($353,200). Total project costs required to obtain these benefits vary widely. Initially, the SR-LR Plan can be eliminated from further consideration since it is not a cost-effective method of providing flood protection to the city of Batavia. The remaining three plans utilize the natural storage capacity of the area upstream from the city and are cost effective based upon their benefit-cost ratios. However, the Batavia Reservoir-Alabama Reservoir Compound scheme was not socially acceptable as it required manipulation of water levels in the existing Alabama swamp area.

B6.61 Construction of the Alexander Reservoir provides average annual flood damage management benefits in Batavia of $192,430 while utilizing only part of the natural capability of the site upstream of the city of Batavia. It is only with the addition of a lower reservoir to supplement the upper reservoir that utilization of the maximum amount of the natural storage capbility of the site is realized. Construction of the Batavia Reservoir would provide greater storage capacity but only at a very large increase in total project costs. The sharp rise in cost is partially associated with the construction of additional dikes and levees and the purchase of the land within the flood pool. Acquisition is necessary within the flood pool since operation of the Batavia Reservoir would eliminate use of this acreage for agricultural or residential purposes. This results in a significant increase in costs and only a small change in flood damage reduction benefits.

B6.62 The economic efficiency of the Selected Plan is measured by the comparison of benefits to costs on an average annual basis and the internal rate of return to the project interest rate.

B6.63 Internal rate of return (IRR) is the interest rate at which the net benefits equal zero. In other words, the IRR is the interest rate which equates the present value of the stream of benefits to the total project cost.

B6.64 Payback method of analysis is the time required for the annual returns from an investment in flood damage management to pay back the initial amount invested. The payback period in years is calculated as the required number of years for the annual benefits to equal the initial investment. The Selected Plan has a total investment cost of $20,054,700. Length of the period by which invested funds will be returned can be a good auxiliary criterion upon which to judge alternatives.

B6.65 A final and more traditional measure of economic efficiency is the comparison of average annual benefits to average annual costs. The benefit-cost ratio (BCR) is the most common measure of economic efficiency for Federal projects and other multipurpose public activities. All of the expected benefits from an alternative are evaluated in monetary terms and totaled in the numerator. The denominator is the sum of all the costs necessary to implement the project. Utilizing this method of evaluation, the ratio of benefits to cost is expected to exceed 1.0 before a project is considered to be economically justified or recommended for further study.

B6.66 Conclusions regarding the economic efficiency of the Selected Plan are as follows: an internal rate of return of 9.625 percent is well above the minimum project interest rate of 6.125 percent, undiscounted annual benefits first equal total project costs in project year 13 (1992) whereas discounted annual benefits equal total project costs in project year 23 (2002), and a BCR of 1.46 indicates that an expenditure of $20,054,700 for flood damage management in the watershed is an efficient use of Federal construction funds.

(4) Benefit Cost Ratios for the Remaining Plans

B6.67 A summary of all the flood damage management plans, total average annual benefits, costs, net benefits and benefit-cost ratios are summarized in Table B53.

Table B53 - Economic Justification of Alternate Plans

	Non-Structural Base Plan	Sierks Reservoir and Linden Reservoir	Sierks Reservoir and Alabama Reservoir Compound	Alexander Reservoir
Average Annual Benefits	952,600	1,733,200	3,283,700	884,100
Average Annual Costs	1,415,500	2,983,900	3,193,000	695,000
Net Benefits	0	0	90,400	189,1000
Benefit-Cost Ratio	0.67	0.58	1.03	1.27

	Batavia Reservoir Compound	Batavia Reservoir	Batavia Reservoir and Alabama Reservoir Compound	Batavia Project Modification
Average Annual Benefits	1,948,000	1,826,700	3,365,700	329,500
Average Annual Costs	1,322,000	1,848,700	2,836,500	130,000
Net Benefits	616,000	0	529,200	199,500
Benefit-Cost Ratio	1.46	0.99	1.19	2.52

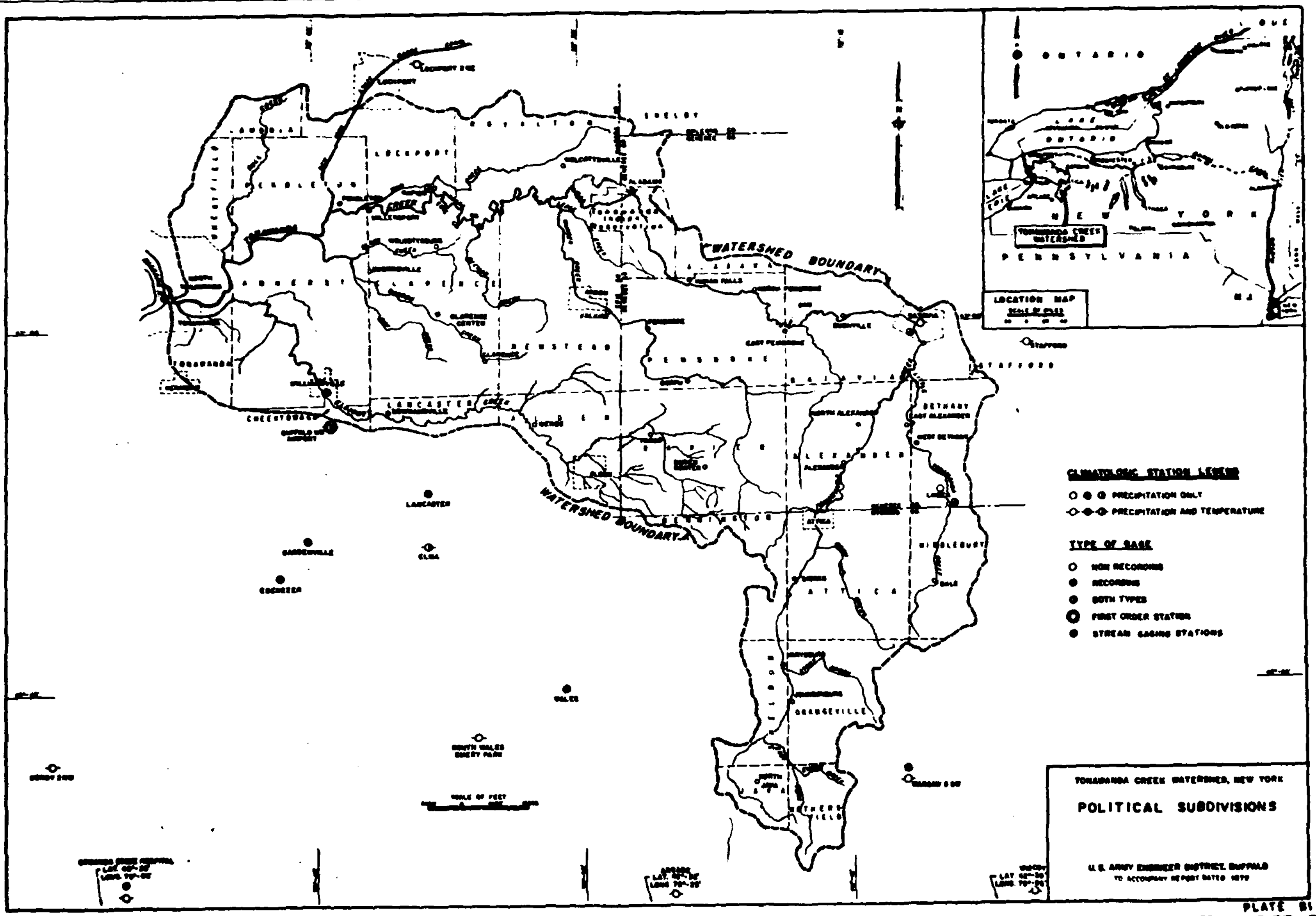
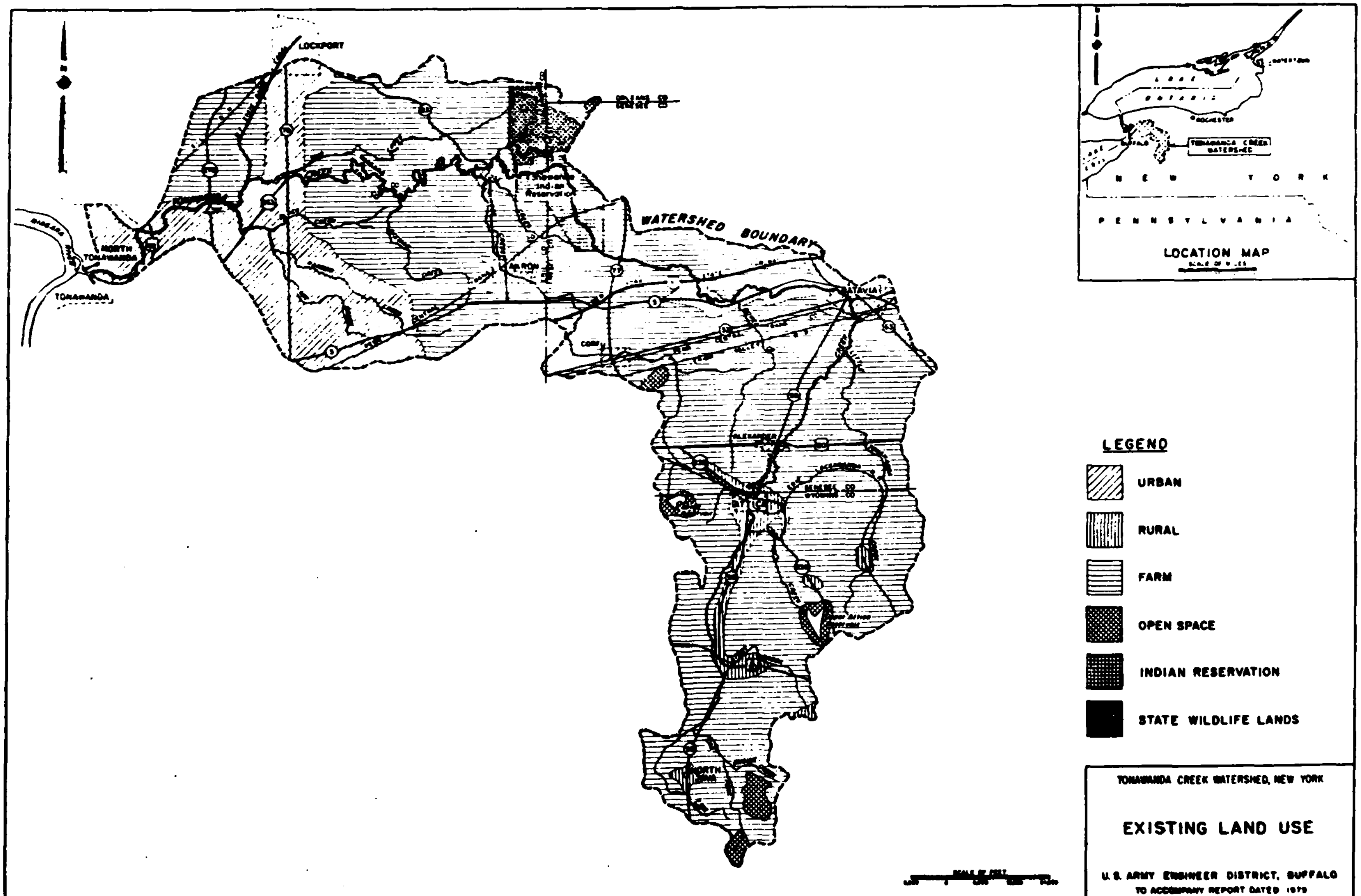

WATERSHED BOUNDARY
WATERSHED BOUNDARY
ONTARIO
NEW YORK
PENNSYLVANIA
LOCATION MAP
CLIMATOLOGIC STATION LEGEND
PRECIPITATION ONLY
PRECIPITATION AND TEMPERATURE
TYPE OF GAGE
NON RECORDING
RECORDING
BOTH TYPES
FIRST ORDER STATION
STREAM GAGING STATIONS
LOCKPORT
ROYALTON
SHELBY
AMHERST
CLARENCE
NEWSTEAD
PENNDROKE
ALEXANDER
ATTICA
BETHANY
STAFFORD
GRANGEVILLE
TONAWANDA CREEK WATERSHED, NEW YORK
POLITICAL SUBDIVISIONS
U.S. ARMY ENGINEER DISTRICT, BUFFALO

PLATE B1

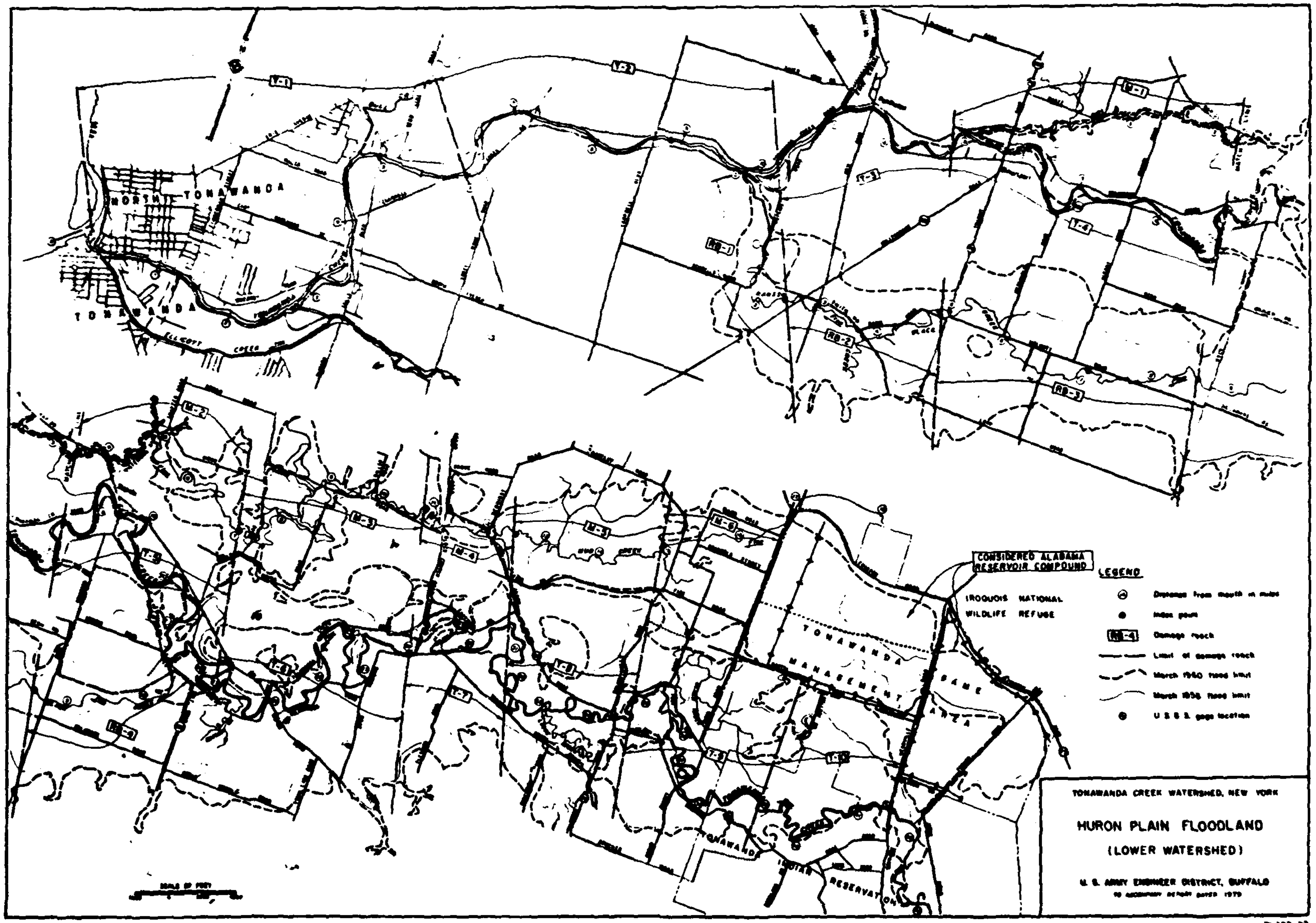


TONAWANDA CREEK WATERSHED, NEW YORK

EXISTING LAND USE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED 1979

PLATE B2



TONAWANDA CREEK WATERSHED, NEW YORK

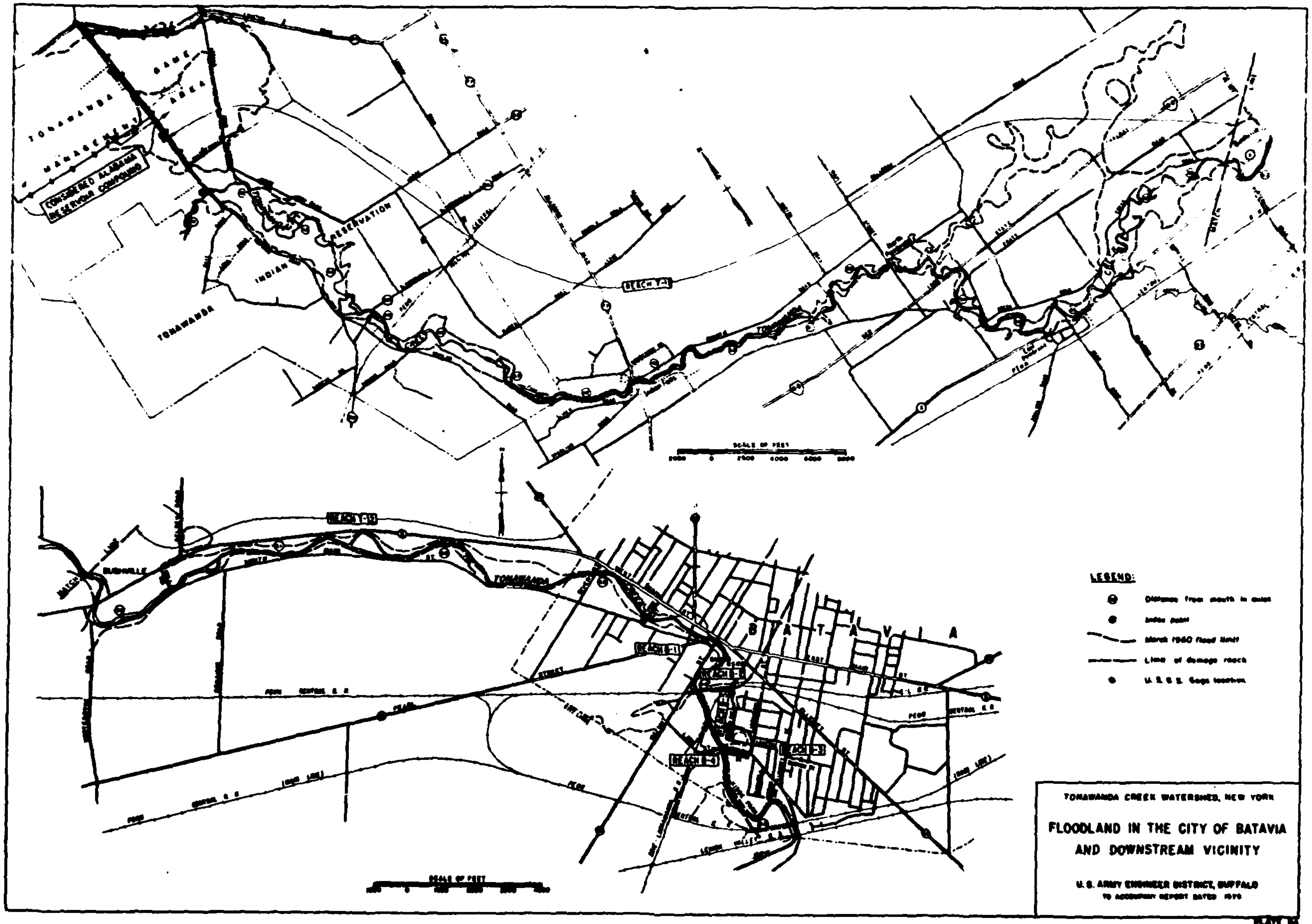
HURON PLAIN FLOODLAND

(LOWER WATERSHED)

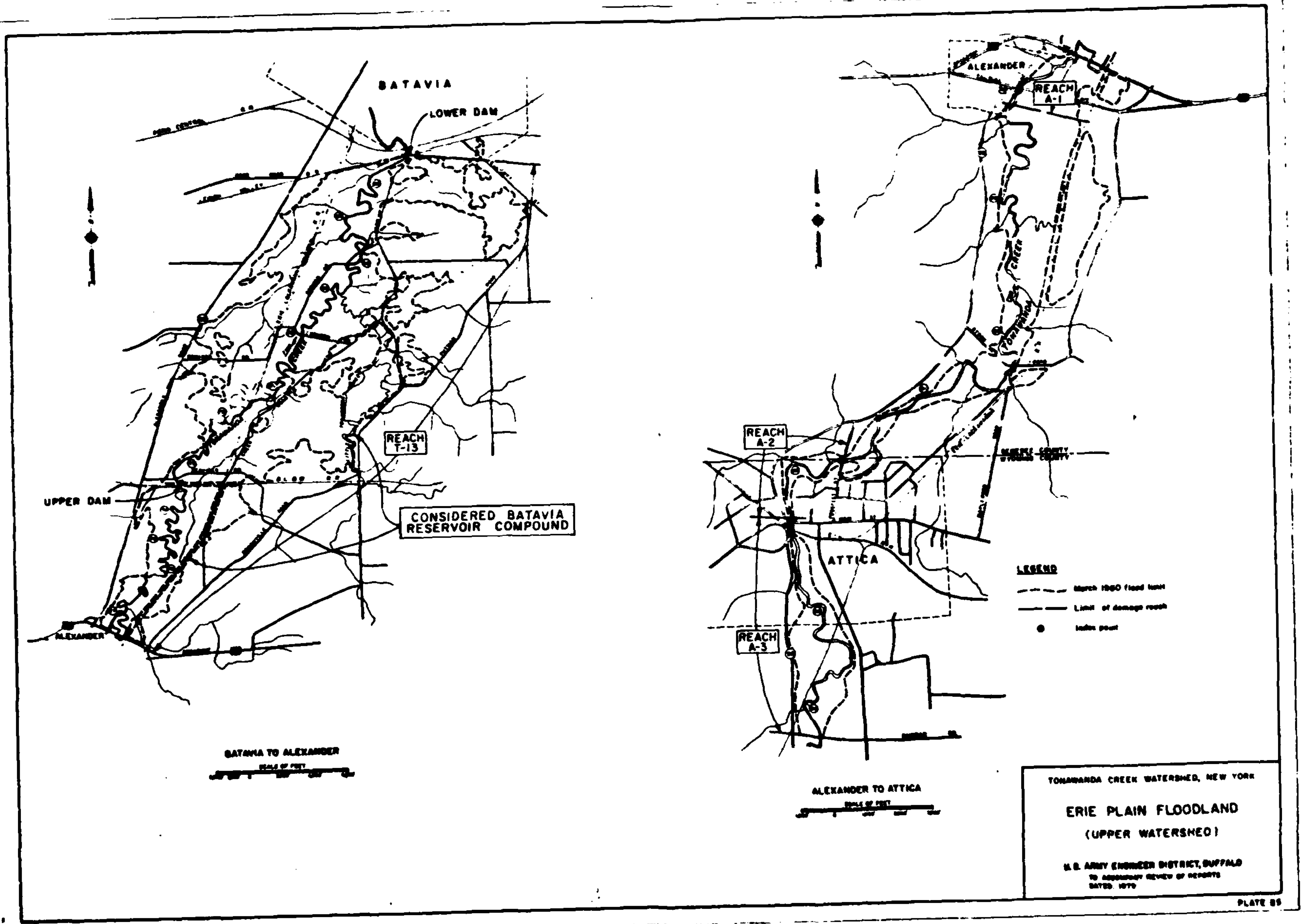
U. S. ARMY ENGINEER DISTRICT, BUFFALO

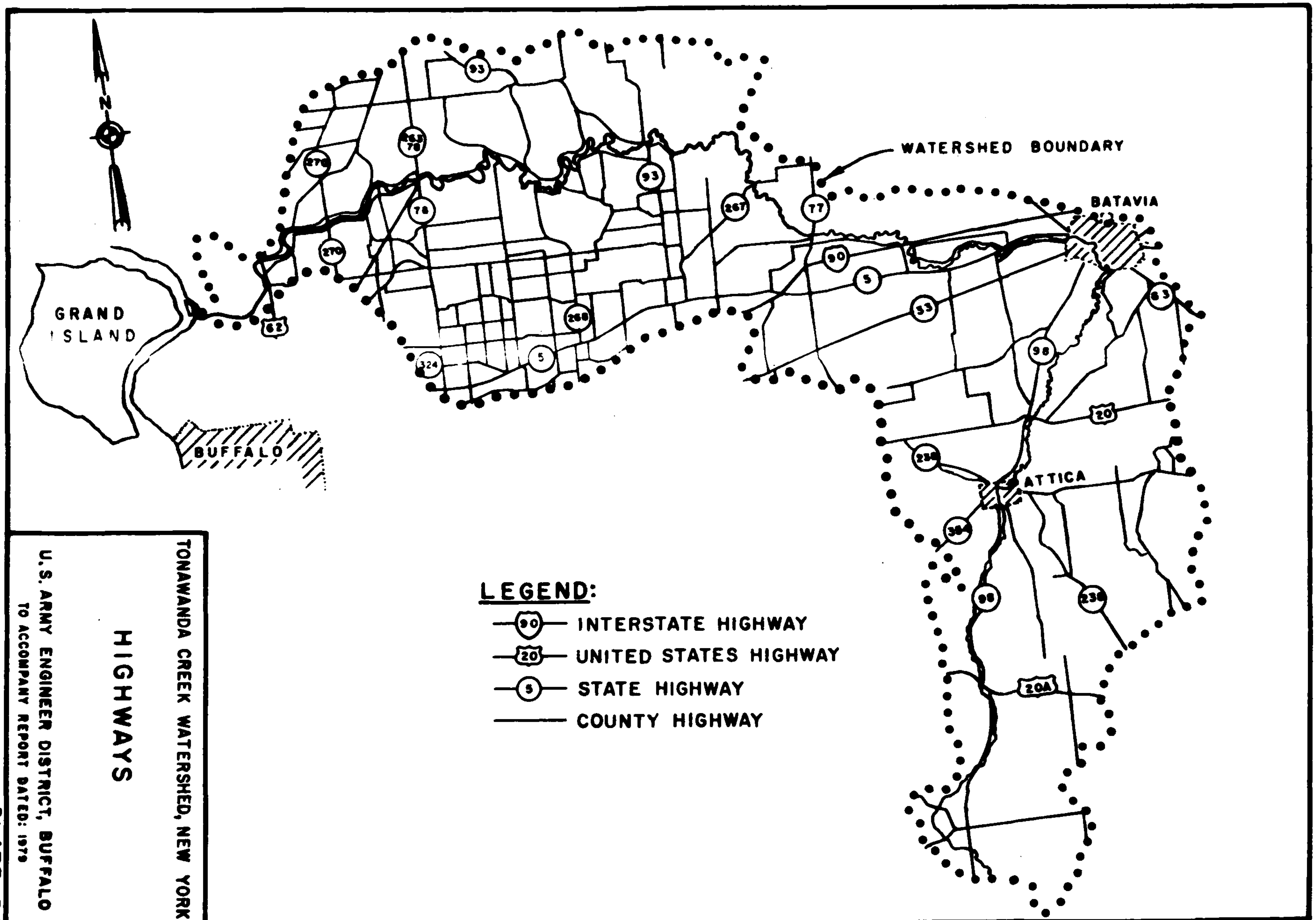
TO ACCOMPANY REPORT DATED 1979

PLATE B3



TONAWANDA
MANAGEMENT
GAME
AREA
CONSIDERED ALABAMA
RESERVOIR COMPOUND
INDIAN
RESERVATION
TONAWANDA
SCALE OF FEET
BATAVIA
LEGEND:
TONAWANDA CREEK WATERSHED, NEW YORK
FLOODLAND IN THE CITY OF BATAVIA
AND DOWNSTREAM VICINITY
U. S. ARMY ENGINEER DISTRICT, BUFFALO


BATAVIA
LOWER DAM
REACH T-13
UPPER DAM
CONSIDERED BATAVIA RESERVOIR COMPOUND
ALEXANDER
BATAVIA TO ALEXANDER
ALEXANDER
REACH A-1
REACH A-2
REACH A-3
ATTICA
LEGEND
March 1960 flood limit
Limit of damage reach
Index point
ALEXANDER TO ATTICA
TONAWANDA CREEK WATERSHED, NEW YORK
ERIE PLAIN FLOODLAND
(UPPER WATERSHED)
U.S. ARMY ENGINEER DISTRICT, BUFFALO
PLATE 85



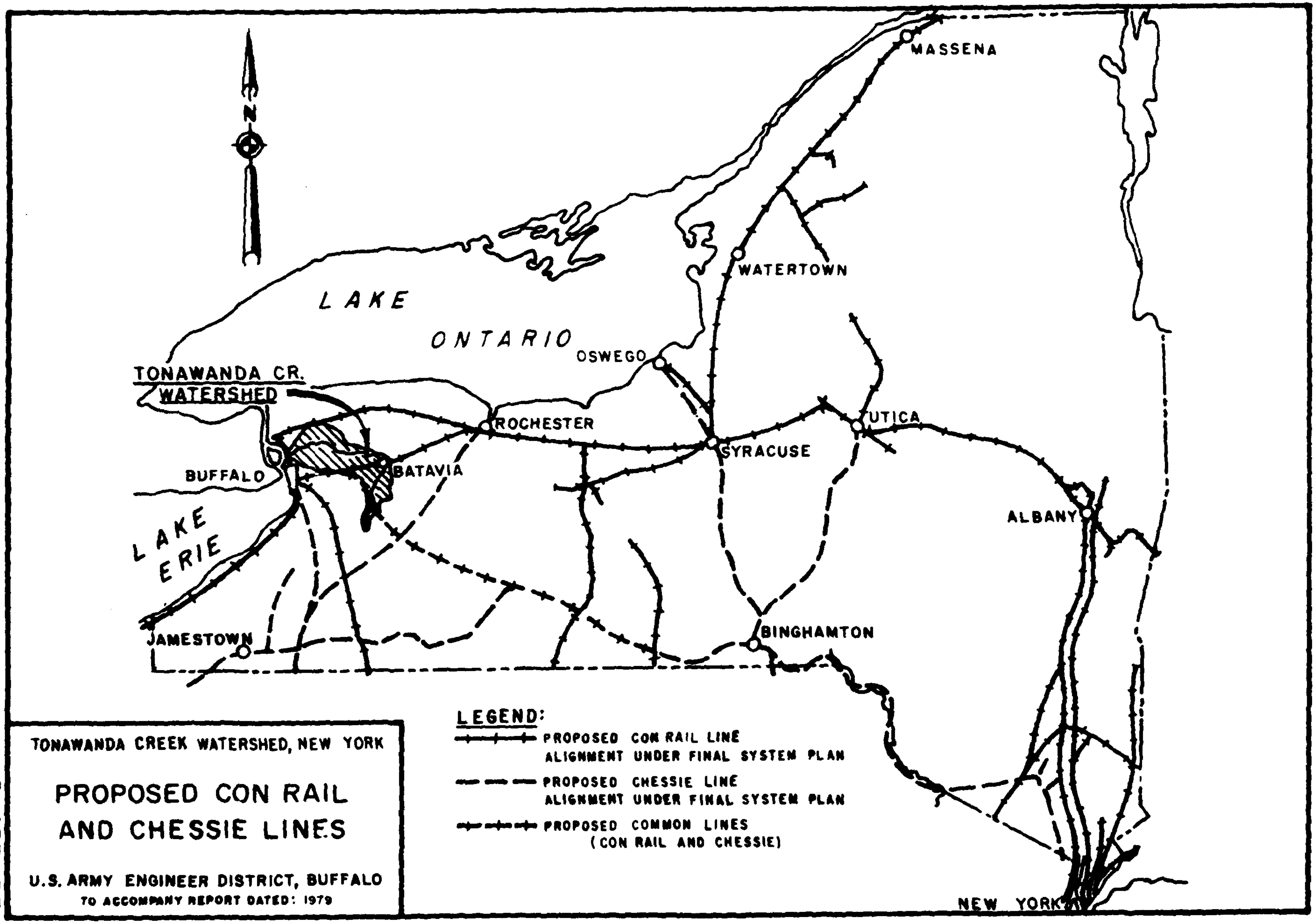
TONAWANDA CREEK WATERSHED, NEW YORK

HIGHWAYS

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B6



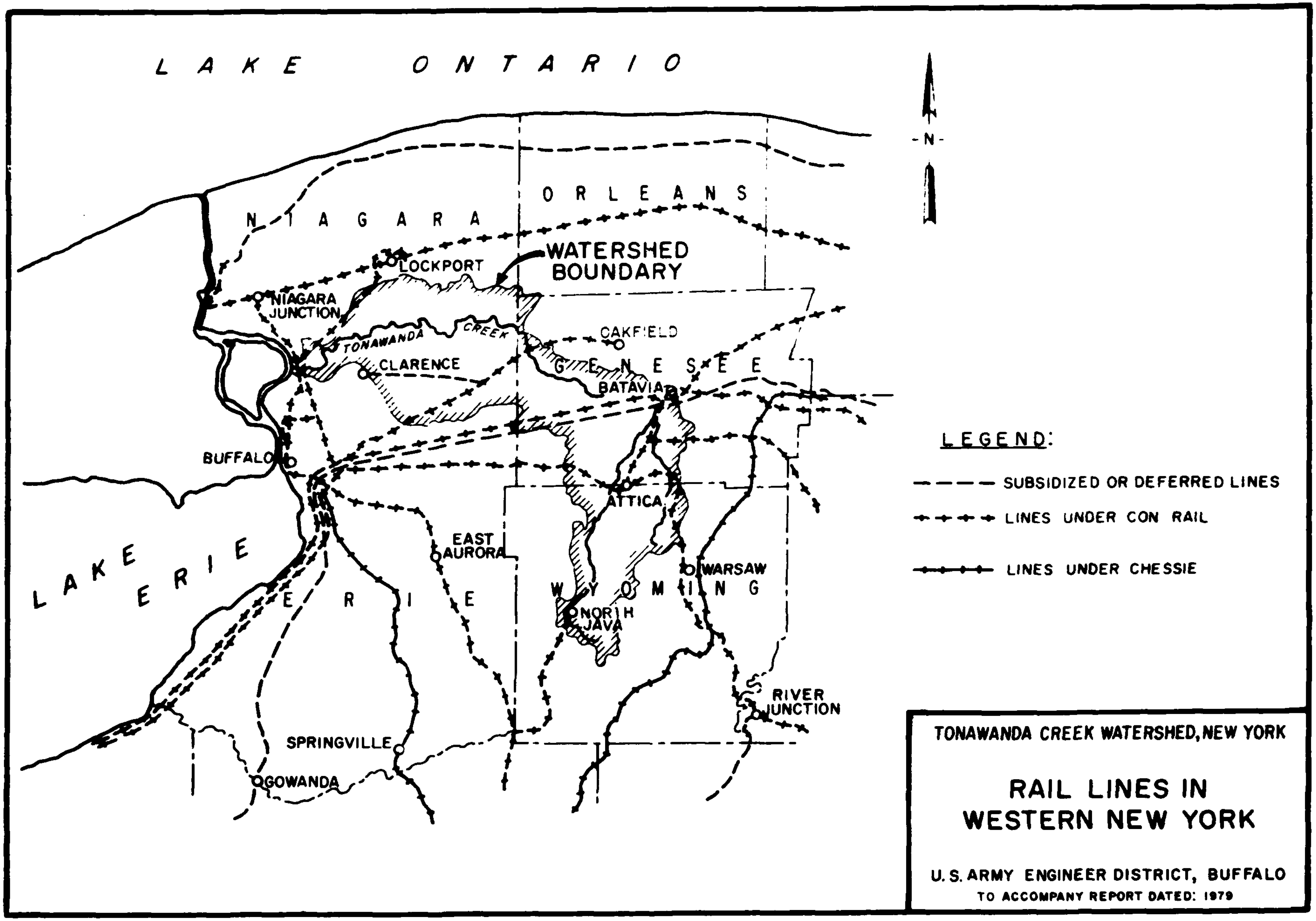
TONAWANDA CREEK WATERSHED, NEW YORK

PROPOSED CON RAIL AND CHESSIE LINES

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B7



TONAWANDA CREEK WATERSHED, NEW YORK

RAIL LINES IN WESTERN NEW YORK

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B8

K•E 20 X 20 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO MADE IN U.S.A.

46 1240

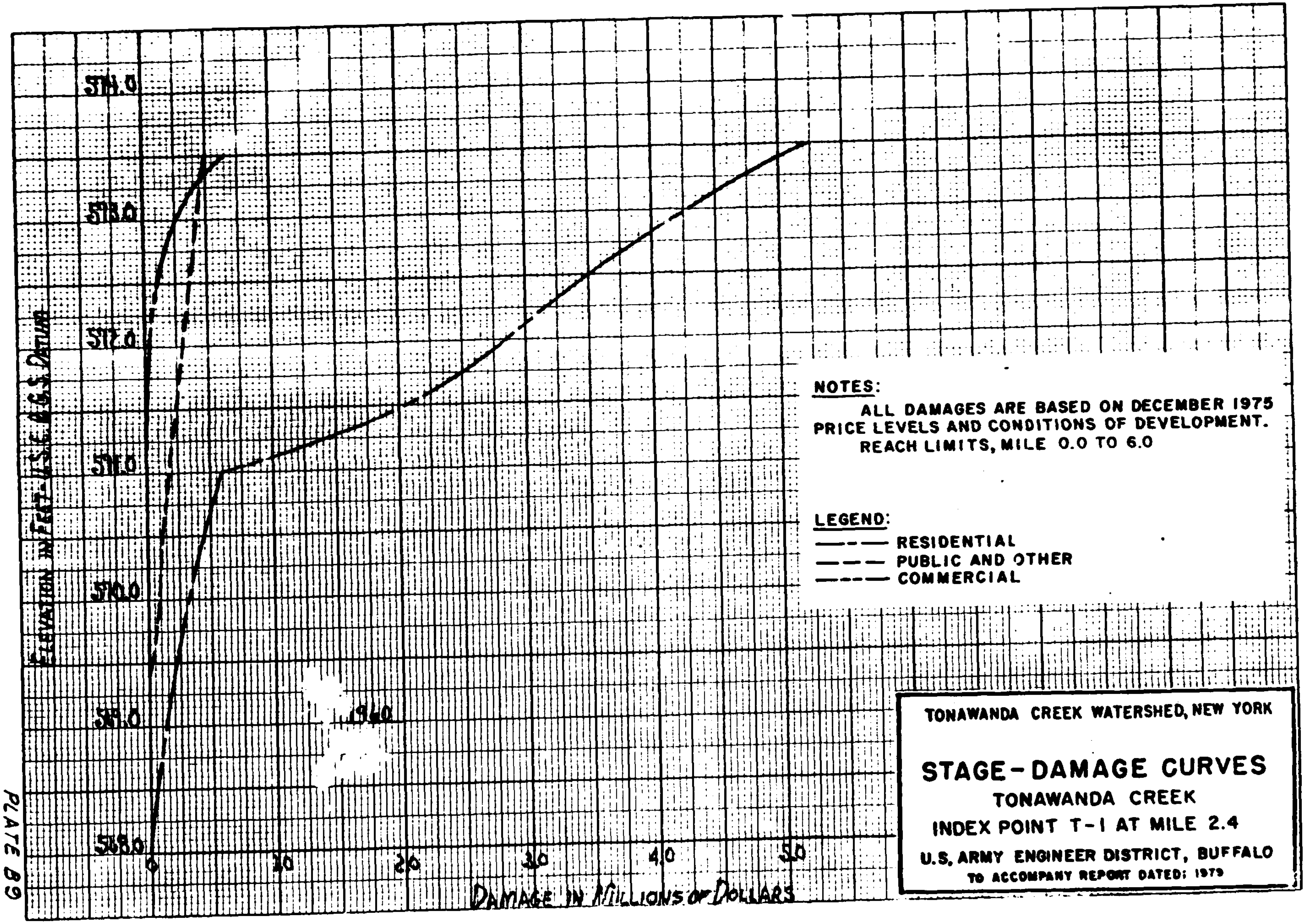
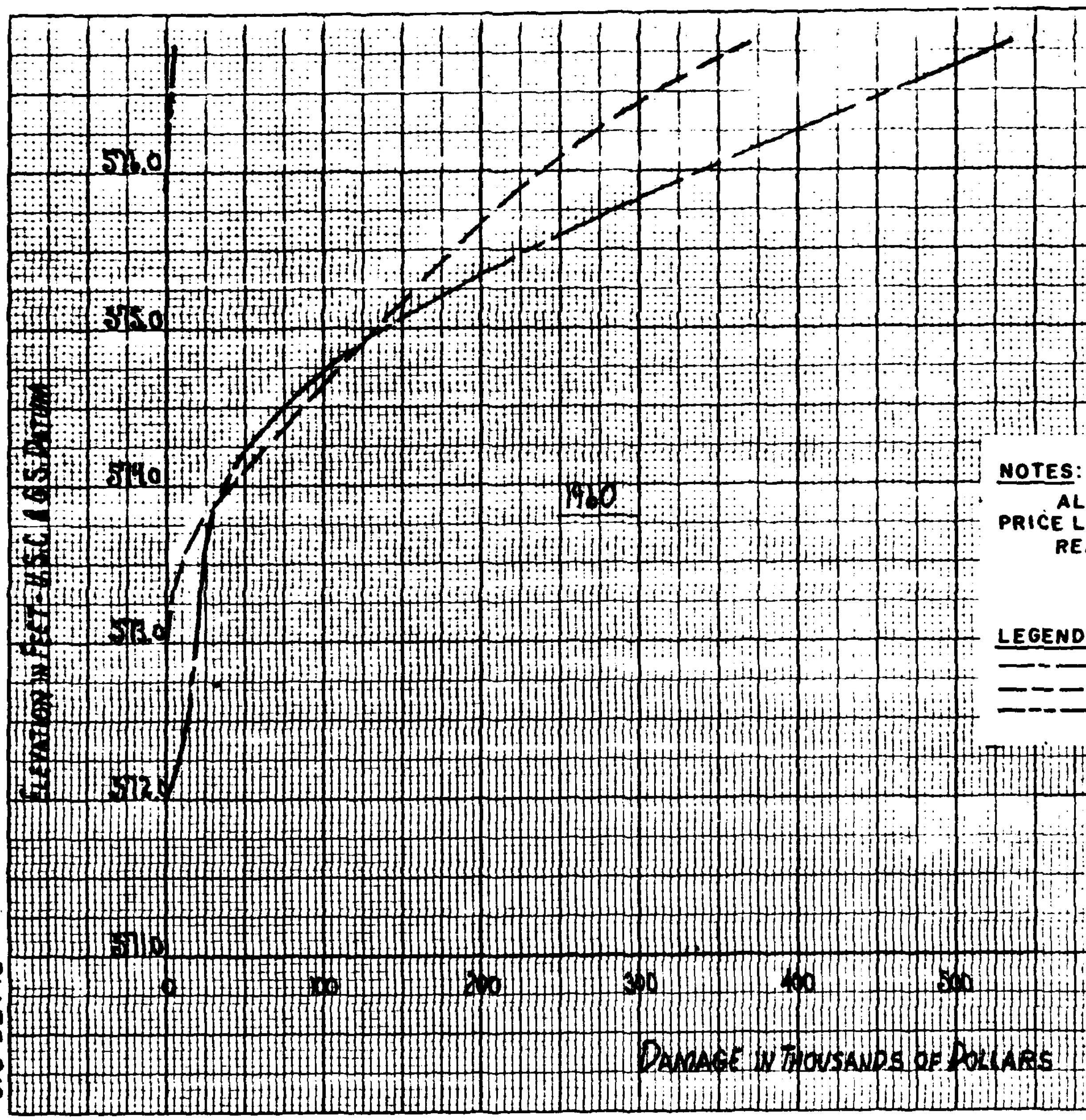


PLATE B9



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONCITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 6.0 TO 10.2

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

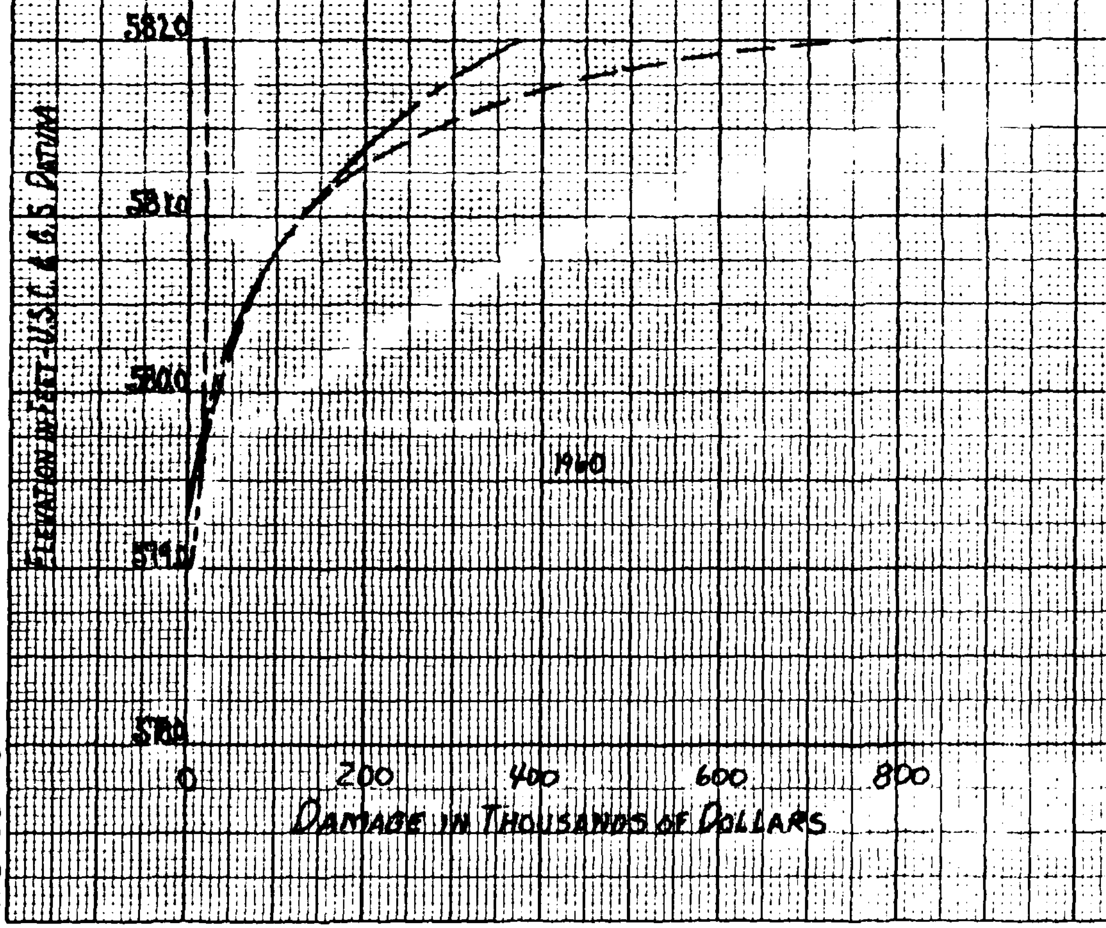
TONAWANDA CREEK

INDEX POINT T-2 AT MILE 8.9

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B10



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 10.2 TO 12.8

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

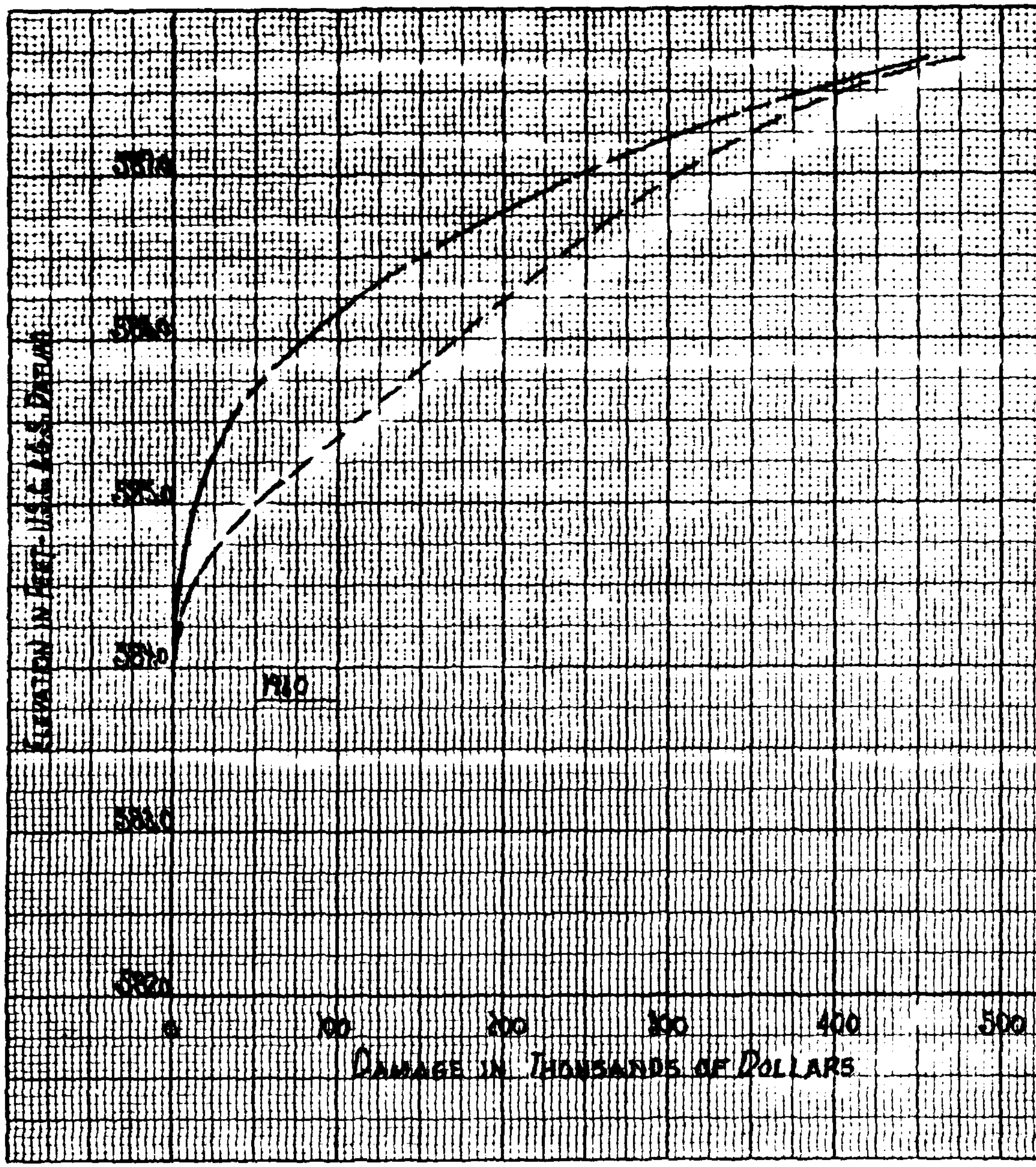
STAGE-DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT T-3 AT MILE 12.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 12.8 TO 17.4

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

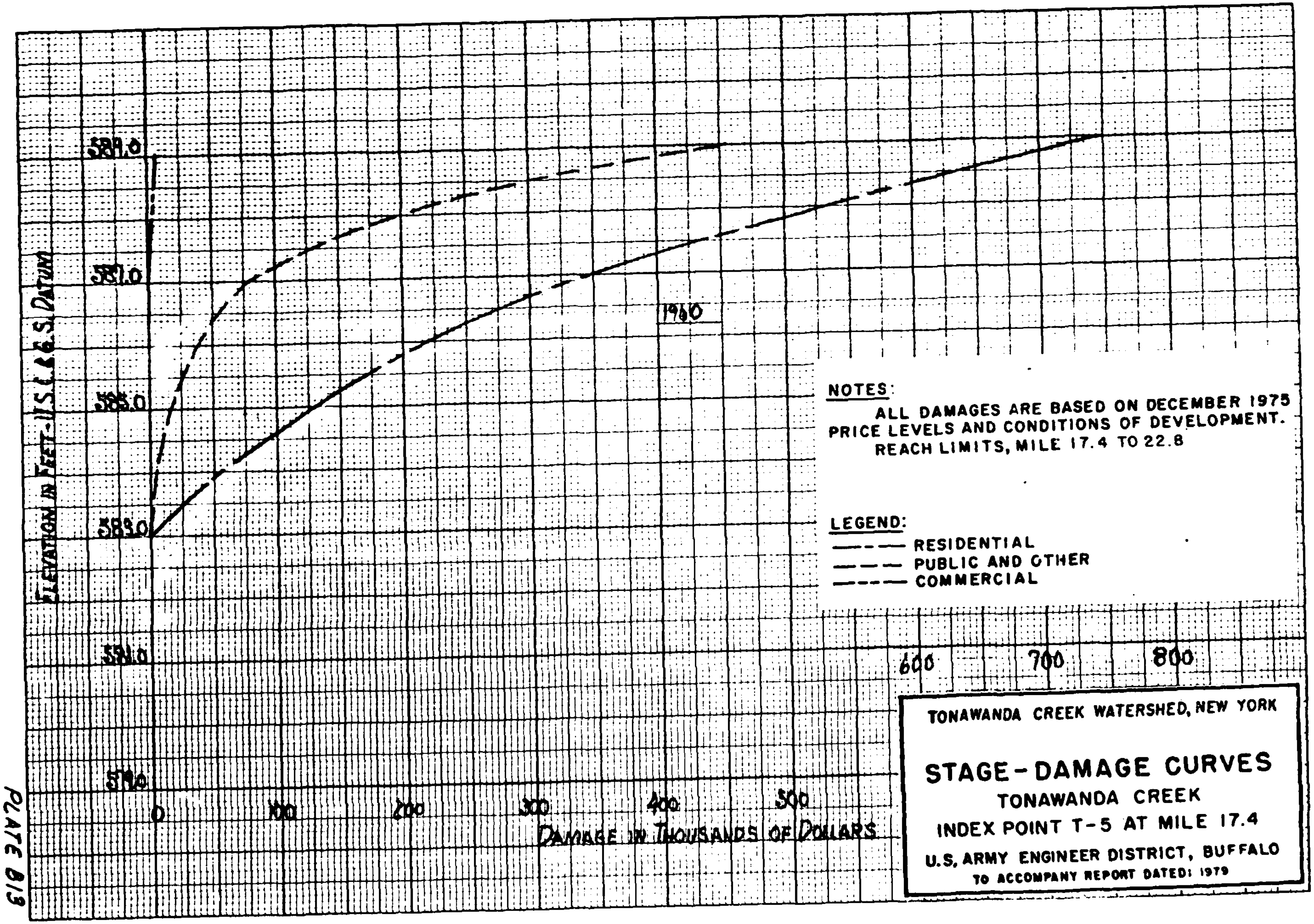
TONAWANDA CREEK

INDEX POINT T-4 AT MILE 15.2

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B12



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT. REACH LIMITS, MILE 17.4 TO 22.8

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

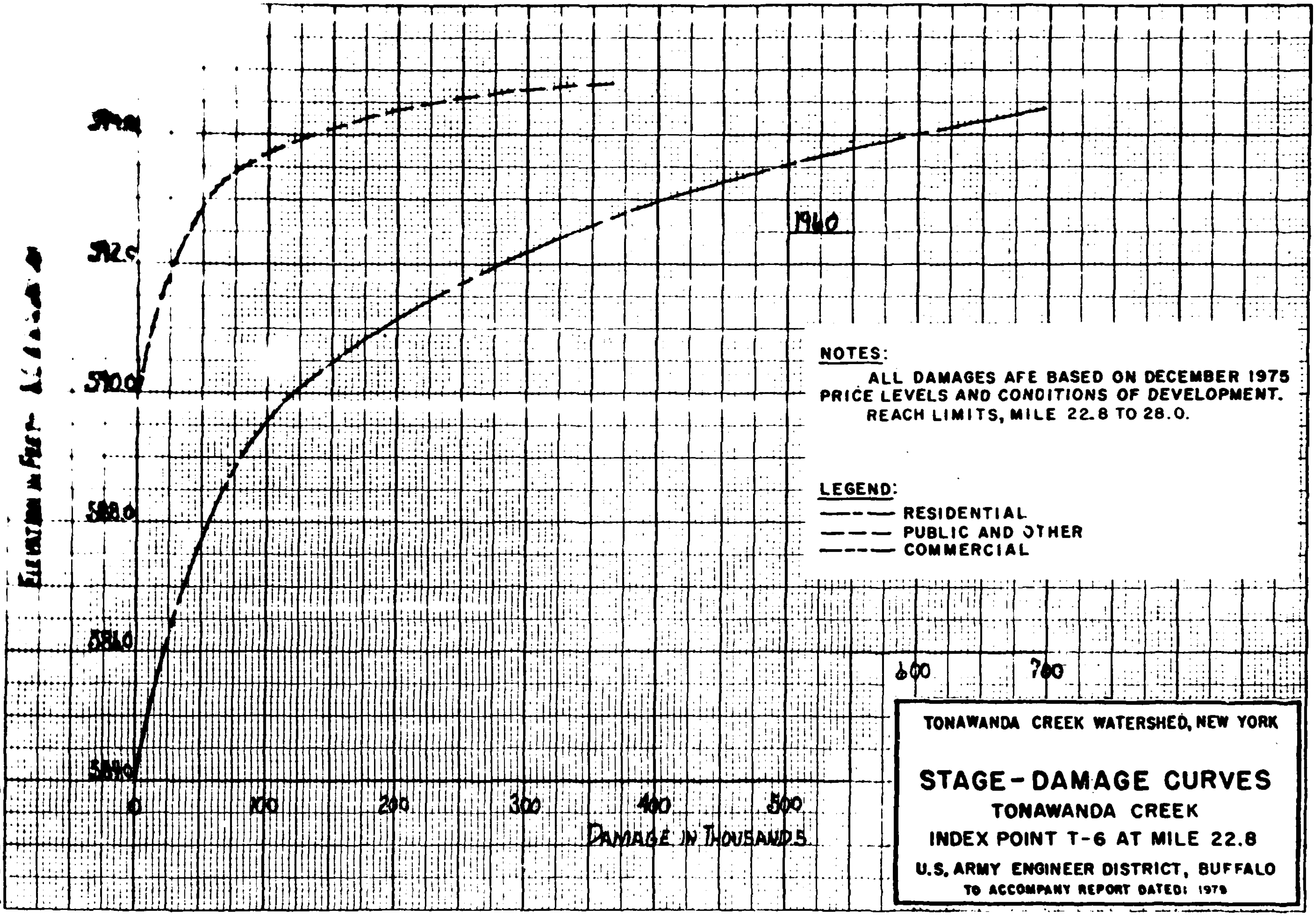
STAGE - DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT T-5 AT MILE 17.4

U.S. ARMY ENGINEER DISTRICT, BUFFALO

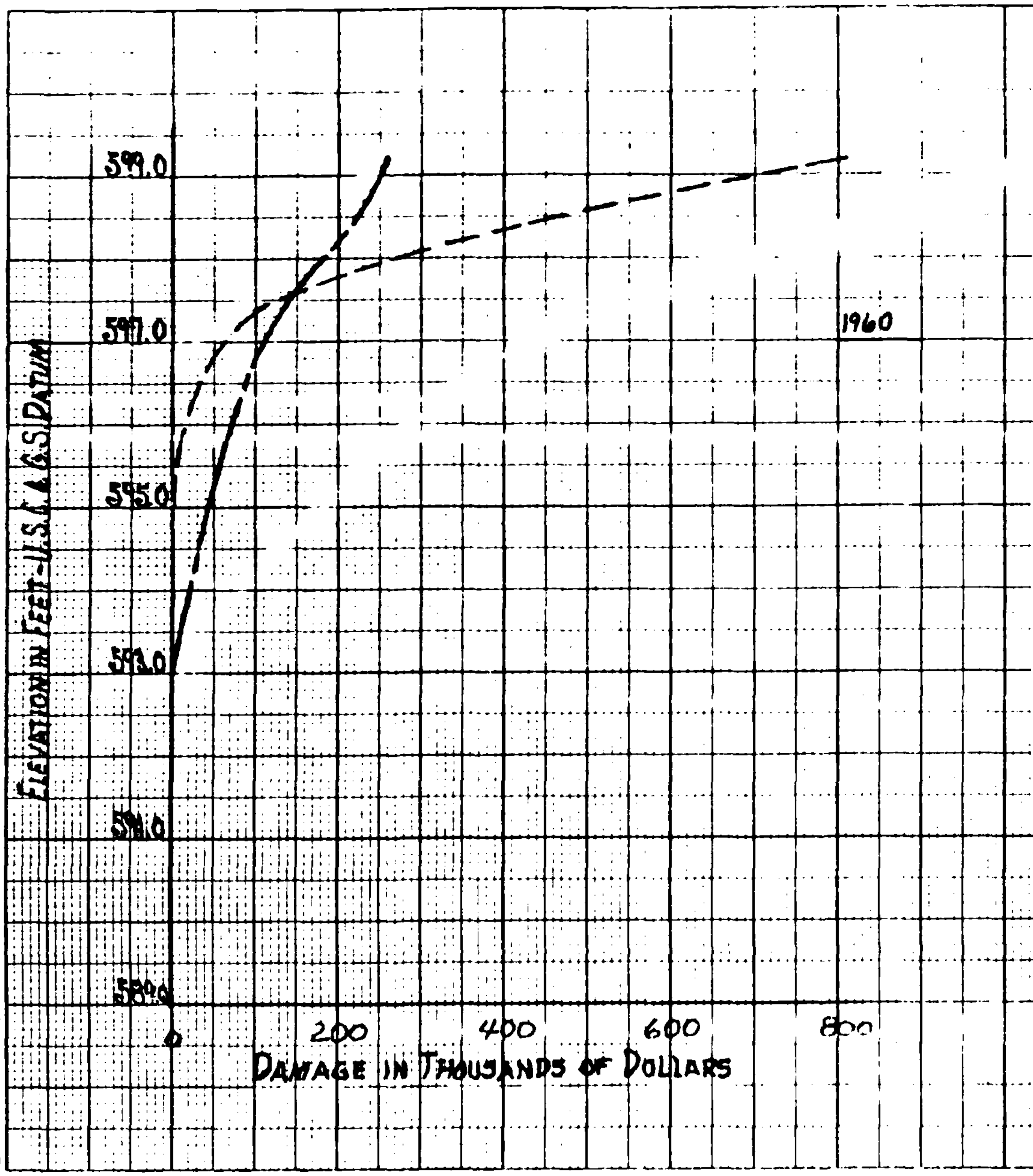
TO ACCOMPANY REPORT DATED: 1979



ELEVATION IN FEET
592.0
590.0
588.0
586.0
584.0
0
100
200
300
400
500
600
700
DAMAGE IN THOUSANDS
1960
NOTES:
ALL DAMAGES AFE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 22.8 TO 28.0.
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-DAMAGE CURVES
TONAWANDA CREEK
INDEX POINT T-6 AT MILE 22.8
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE B-4

K·E 20 X 20 TO THE INCH KEUFFEL & ESSER CO. 46 1240



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 28.0 TO 32.3

LEGEND:

RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT T-7 AT MILE 28.0

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

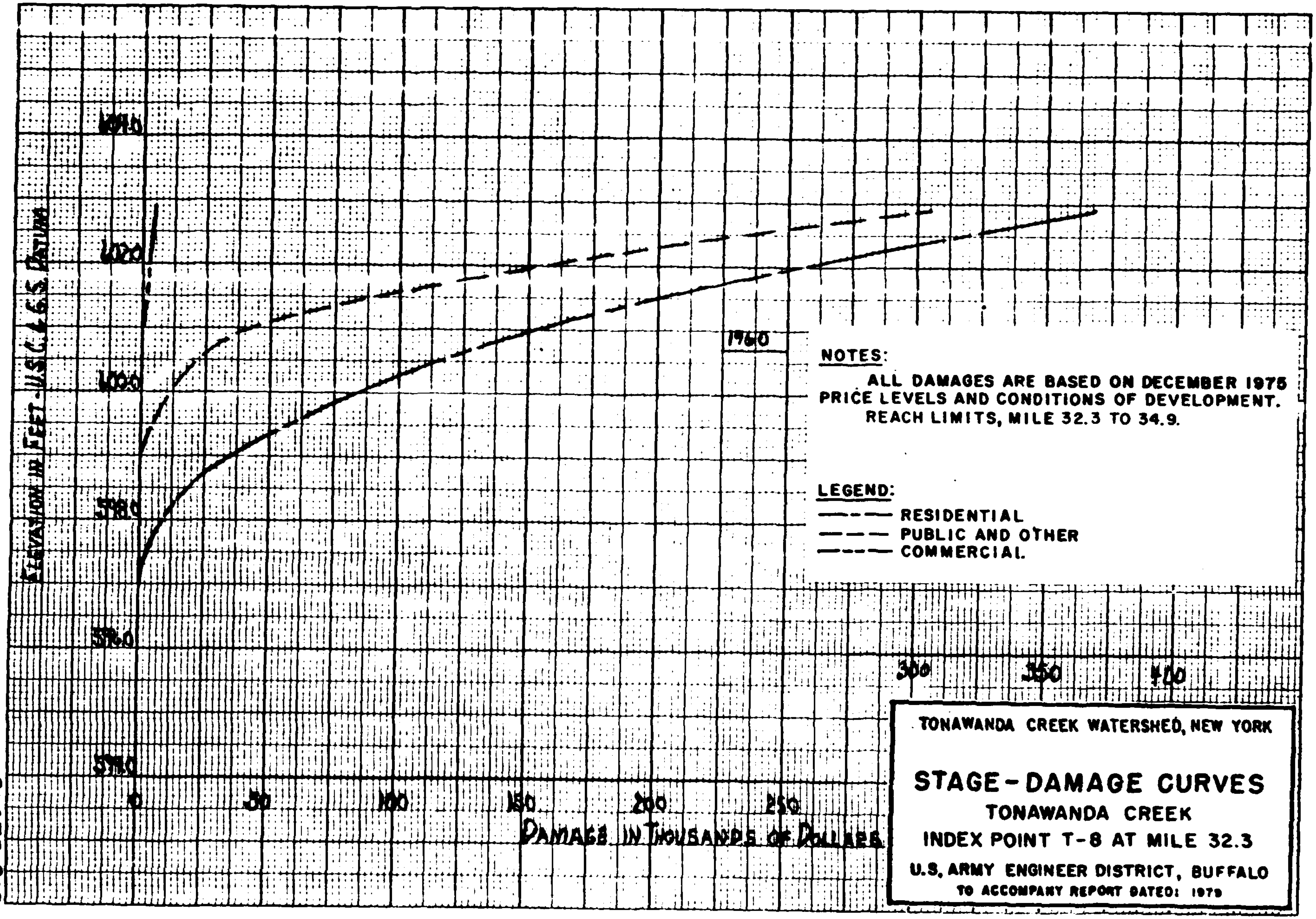
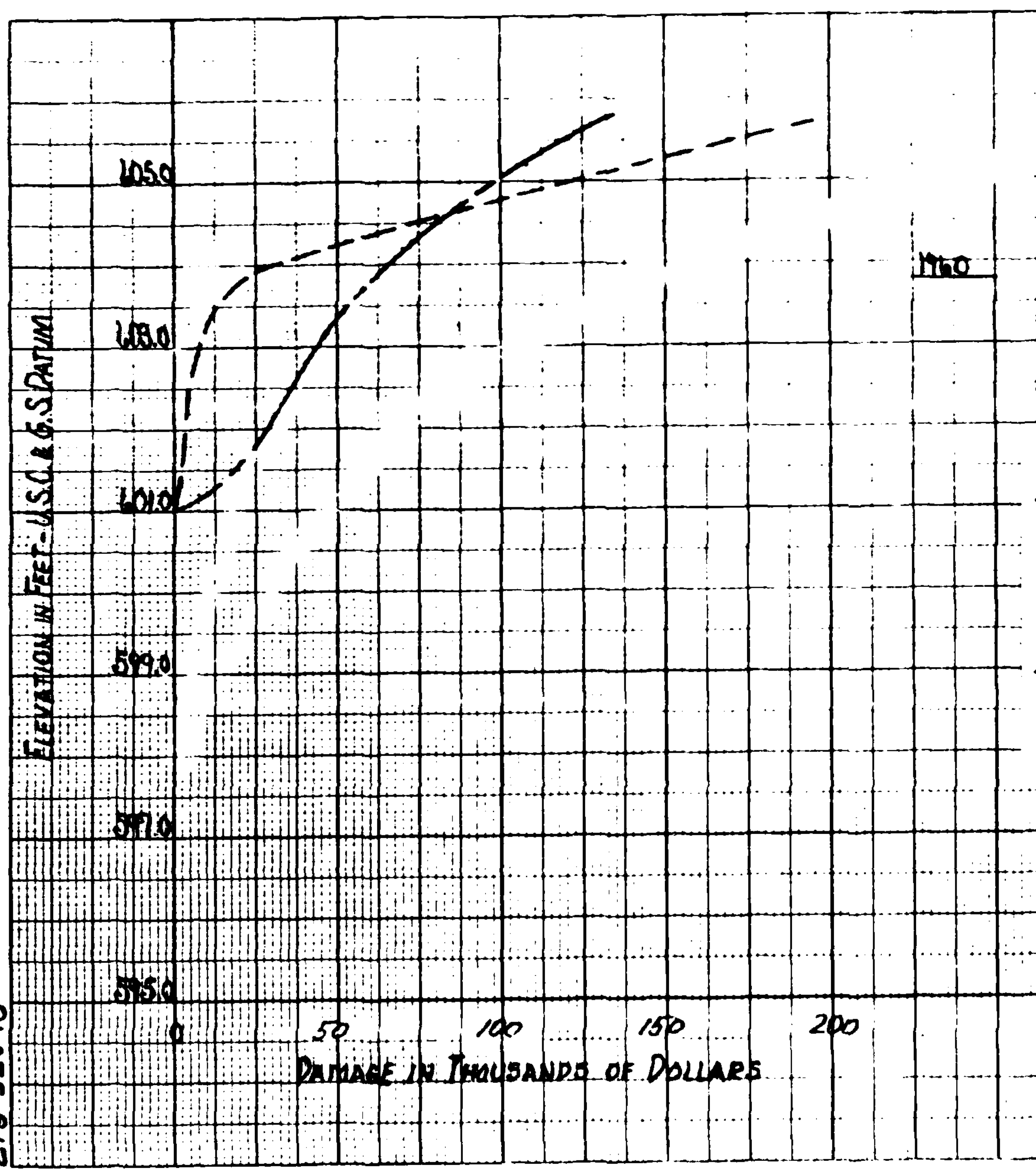

NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 32.3 TO 34.9.
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
1960
ELEVATION IN FEET - U.S.C. & G.S. DATUM
0
50
100
150
200
250
300
350
400
DAMAGE IN THOUSANDS OF DOLLARS
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE - DAMAGE CURVES
TONAWANDA CREEK
INDEX POINT T-8 AT MILE 32.3
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE B16



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT. REACH LIMITS, MILE 34.9 TO 38.9.

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL.

TONAWANDA CREEK WATERSHED, NEW YORK

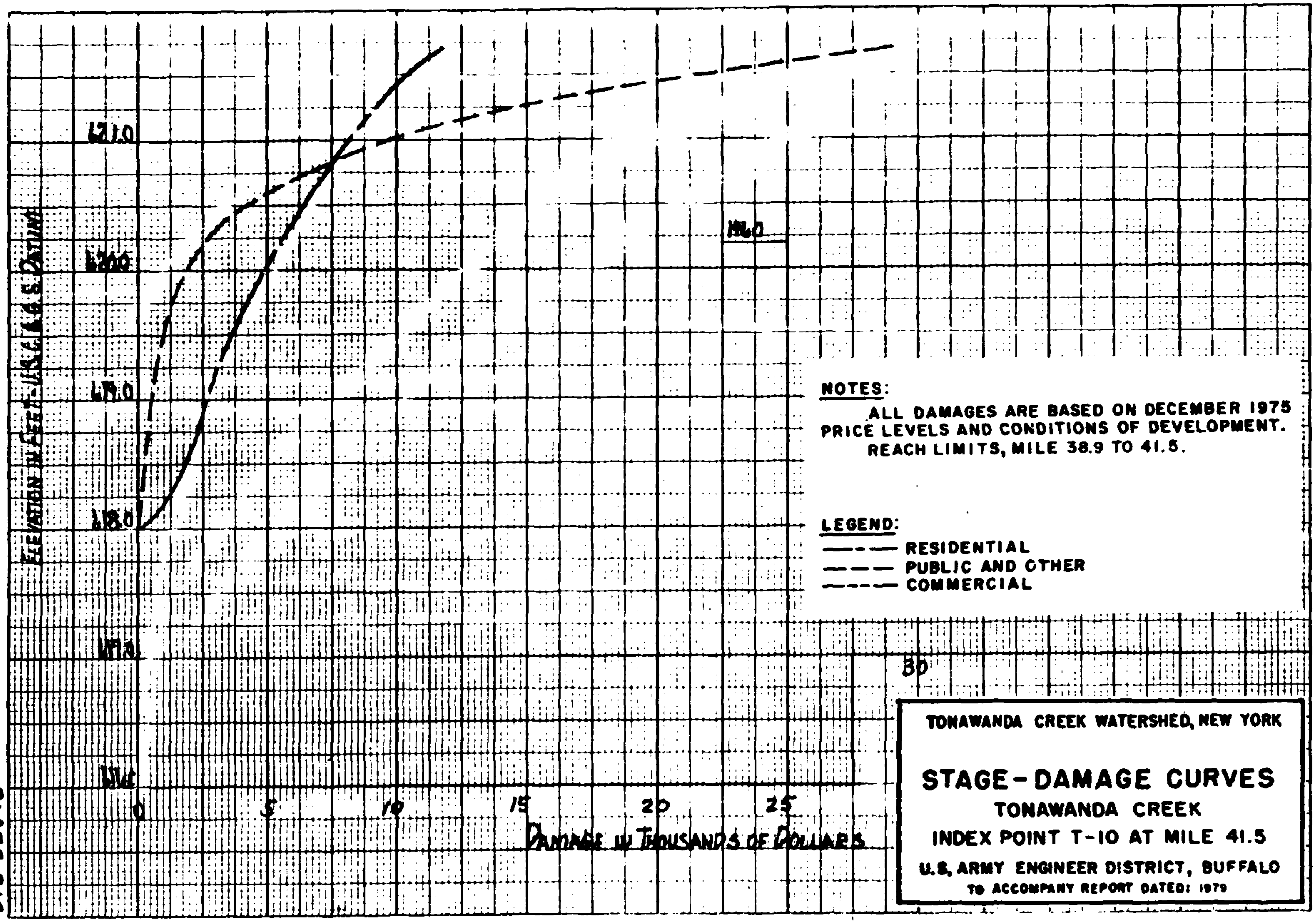
STAGE-DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT T-9 AT MILE 34.9

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 38.9 TO 41.5.

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

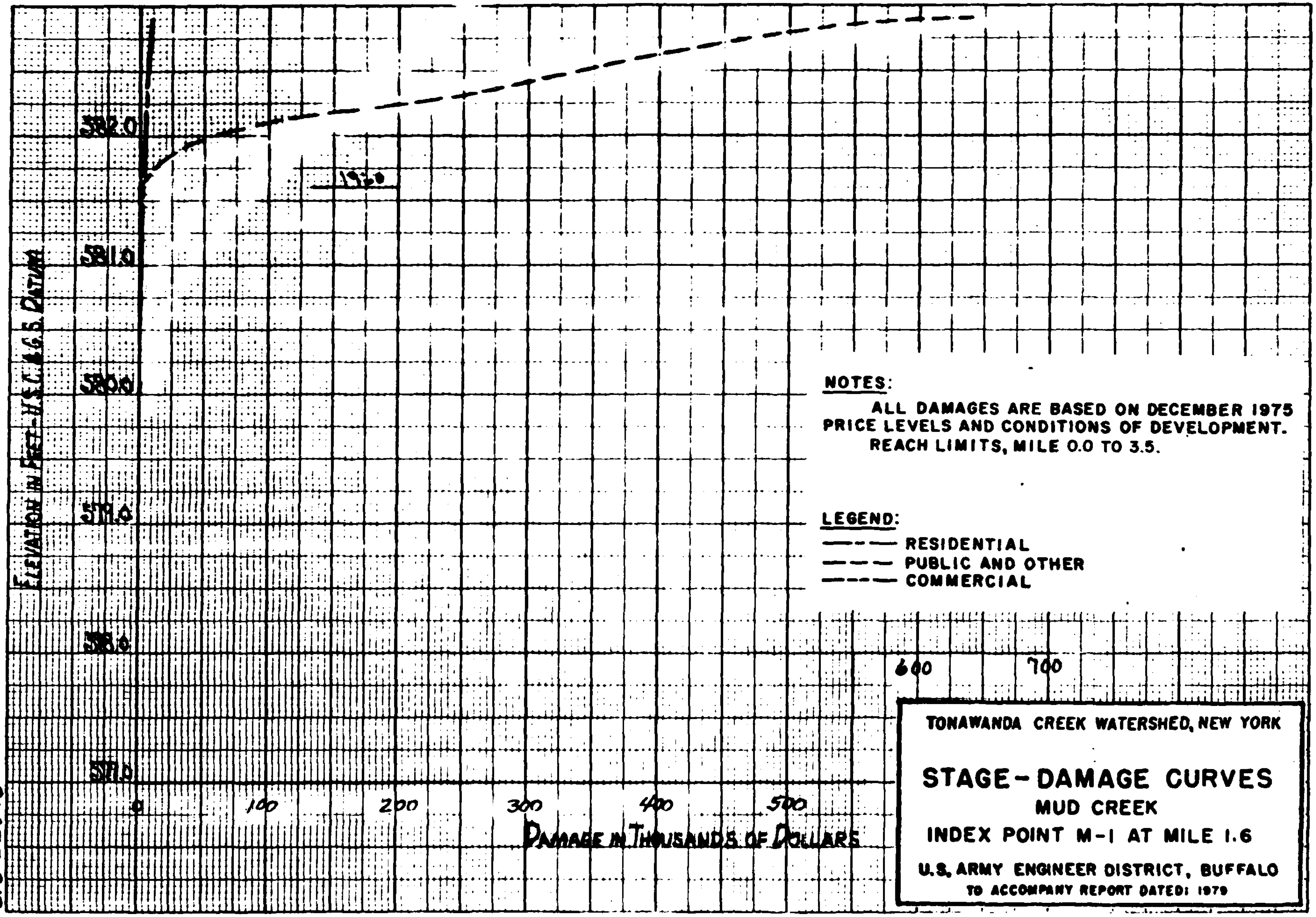
TONAWANDA CREEK

INDEX POINT T-10 AT MILE 41.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B18



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 0.0 TO 3.5.

LEGEND:

—— RESIDENTIAL
— — PUBLIC AND OTHER
- - - COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES
MUD CREEK
INDEX POINT M-1 AT MILE 1.6

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

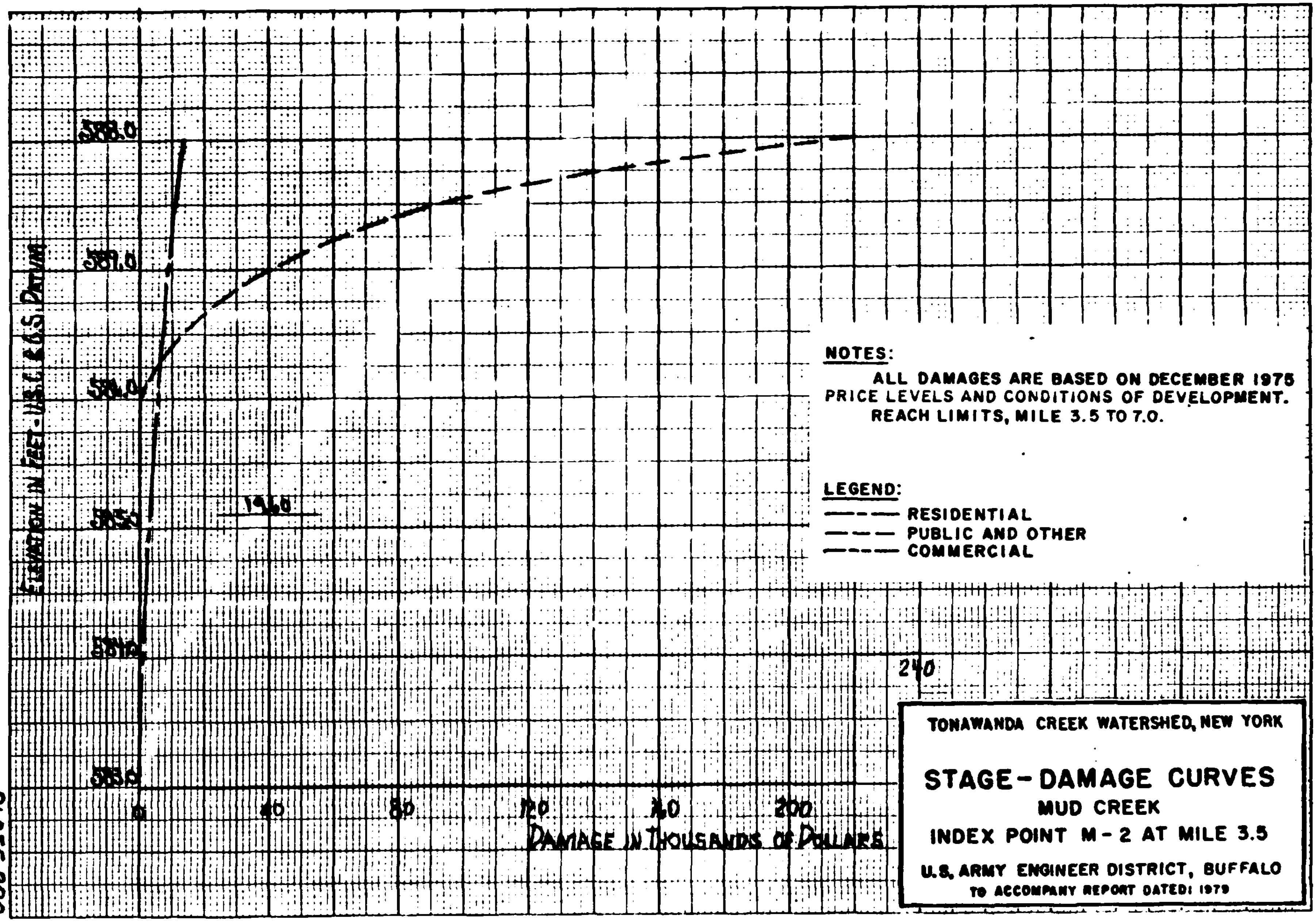
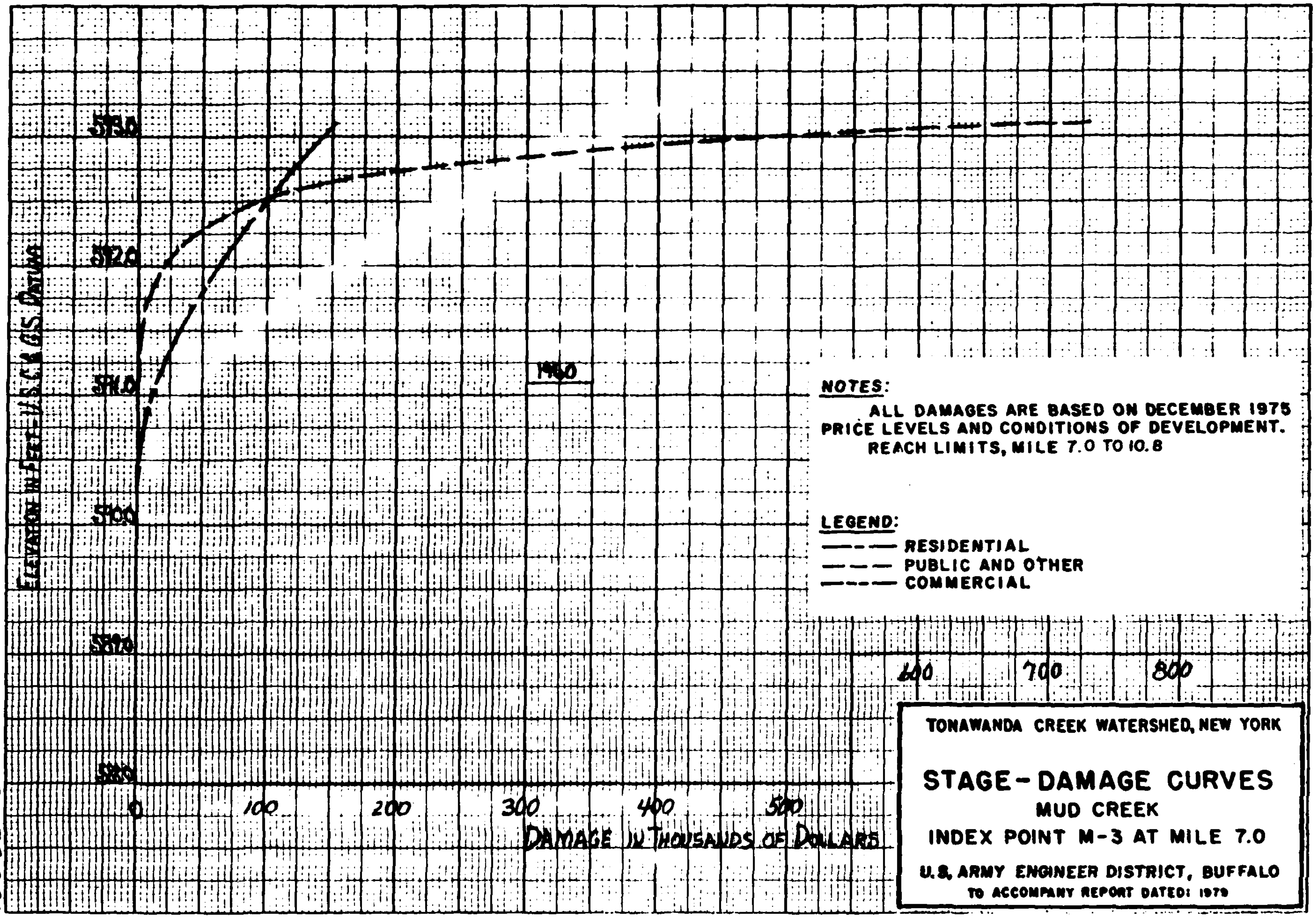

588.0
587.0
586.0
0
40
80
120
200
240
DAMAGE IN THOUSANDS OF DOLLARS
ELEVATION IN FEET - U.S.C.&G.S. DATUM
NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT. REACH LIMITS, MILE 3.5 TO 7.0.
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE - DAMAGE CURVES
MUD CREEK
INDEX POINT M - 2 AT MILE 3.5
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE B20



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT. REACH LIMITS, MILE 7.0 TO 10.8

LEGEND:

- ——— RESIDENTIAL
- — — — PUBLIC AND OTHER
- - - - - COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

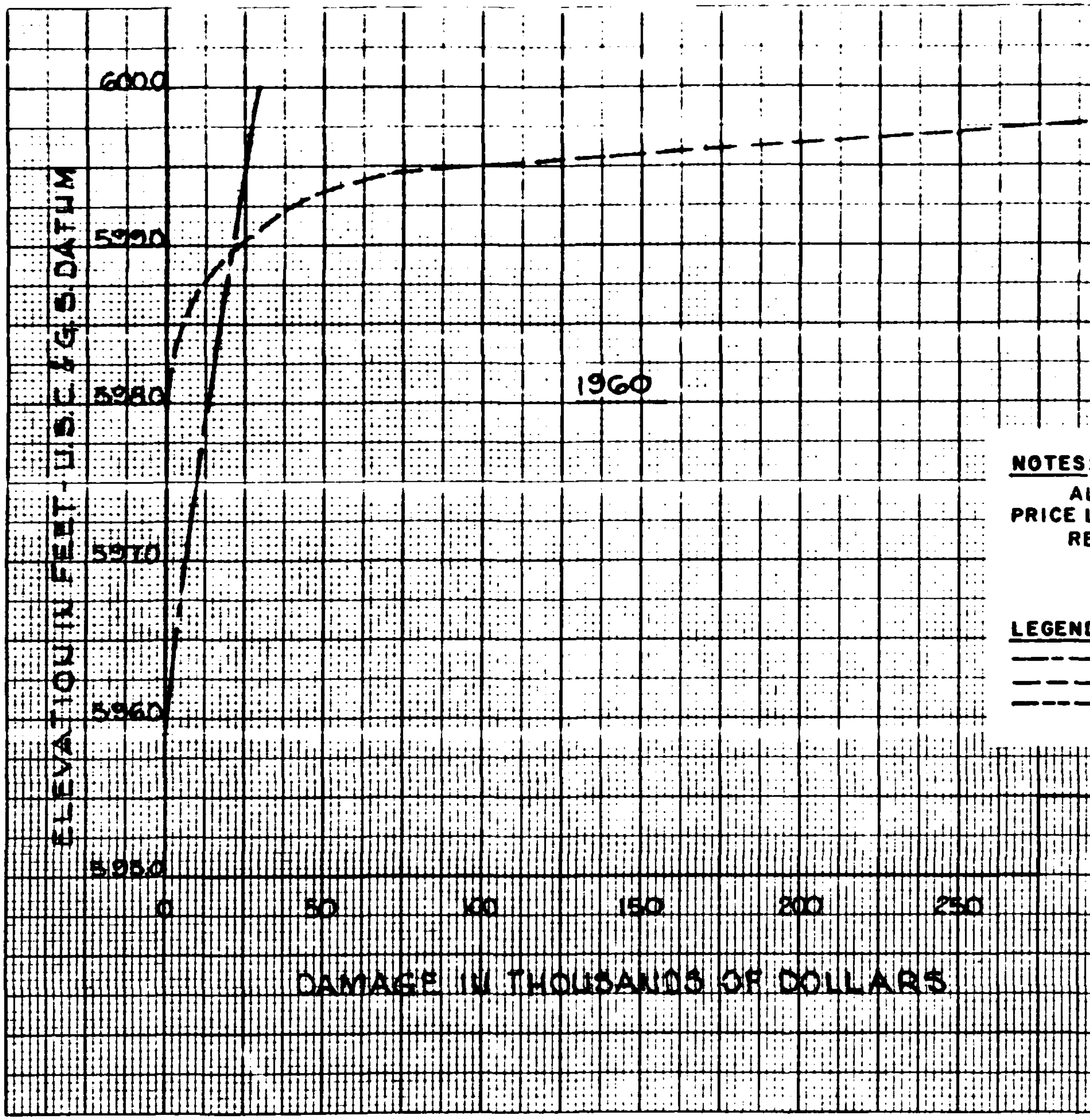
STAGE - DAMAGE CURVES

MUD CREEK

INDEX POINT M-3 AT MILE 7.0

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 10.8 TO 12.3

LEGEND:

- ——— RESIDENTIAL
- — — — PUBLIC AND OTHER
- —-—- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES

MUD CREEK

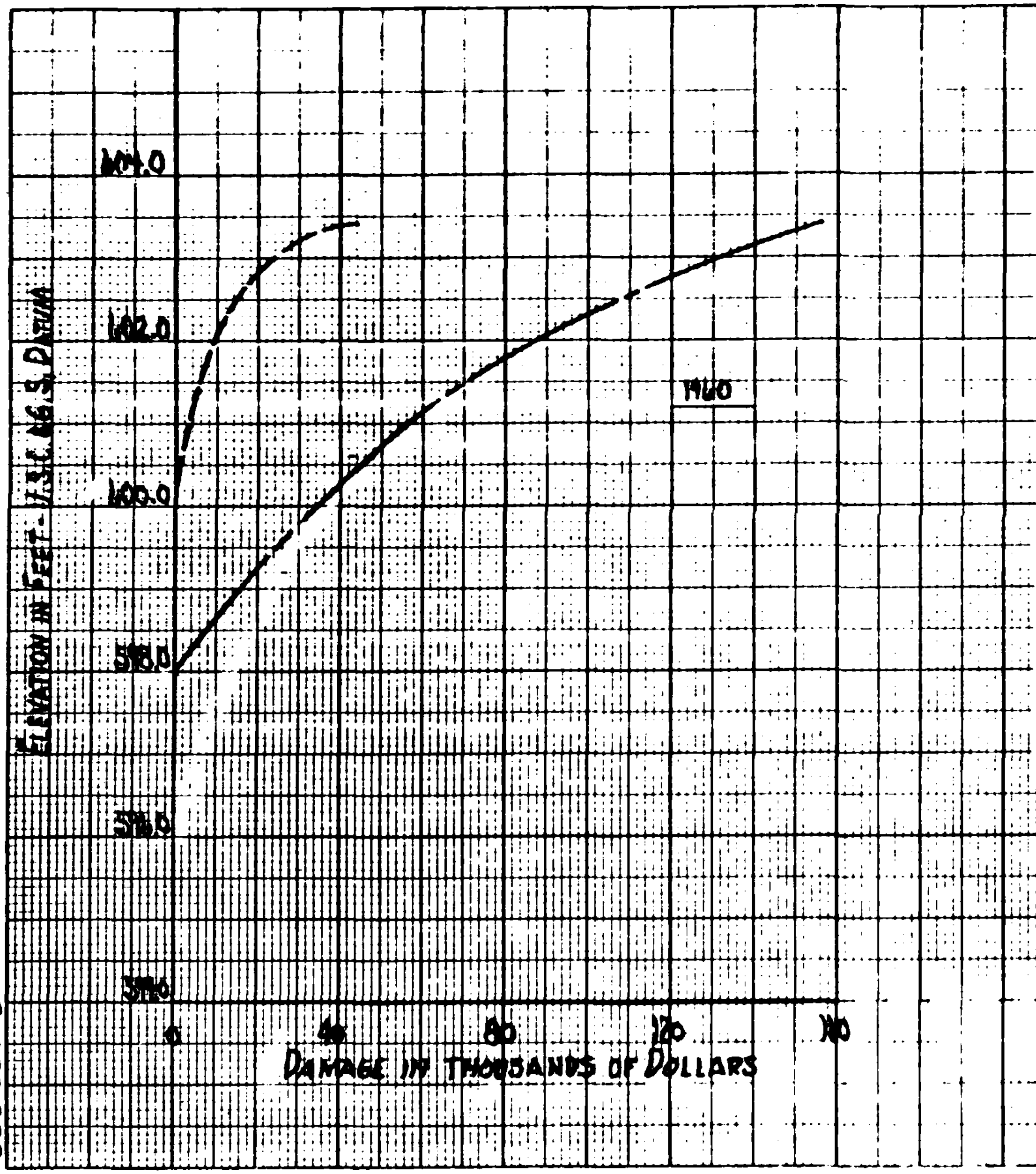
INDEX POINT M-4 AT MILE 10.8

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B22

K·E KEUFFEL & ESSER CO.   46 1240



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 12.3 TO 15.0

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE – DAMAGE CURVES

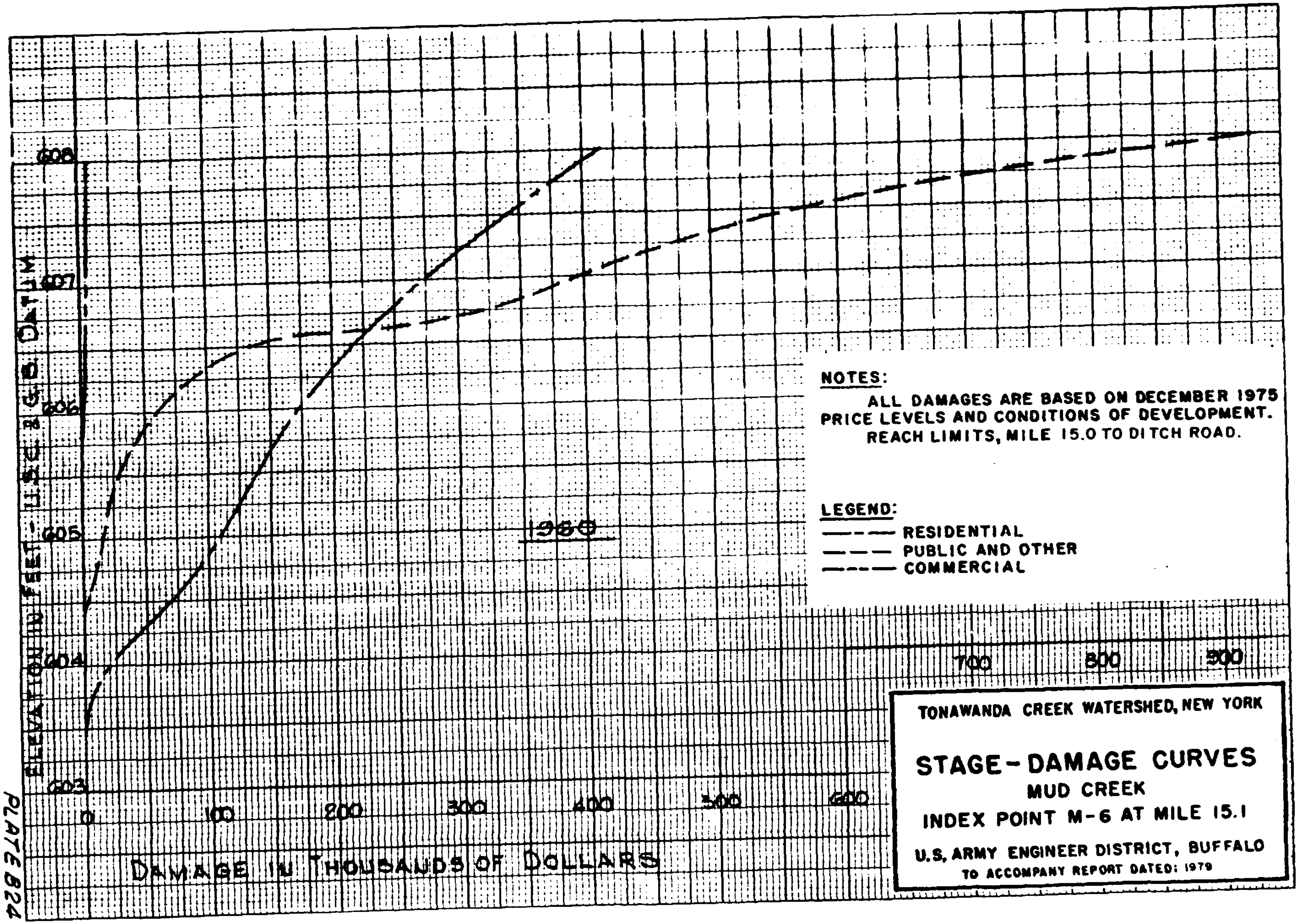
MUD CREEK

INDEX POINT M-5 AT MILE 12.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE 323



608
607
606
605
604
603
0
100
200
300
400
500
600
700
800
900
1960
ELEVATION IN FEET - U.S.C. & G.S. DATUM
DAMAGE IN THOUSANDS OF DOLLARS
NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 15.0 TO DITCH ROAD.
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-DAMAGE CURVES
MUD CREEK
INDEX POINT M-6 AT MILE 15.1
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE B24

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320

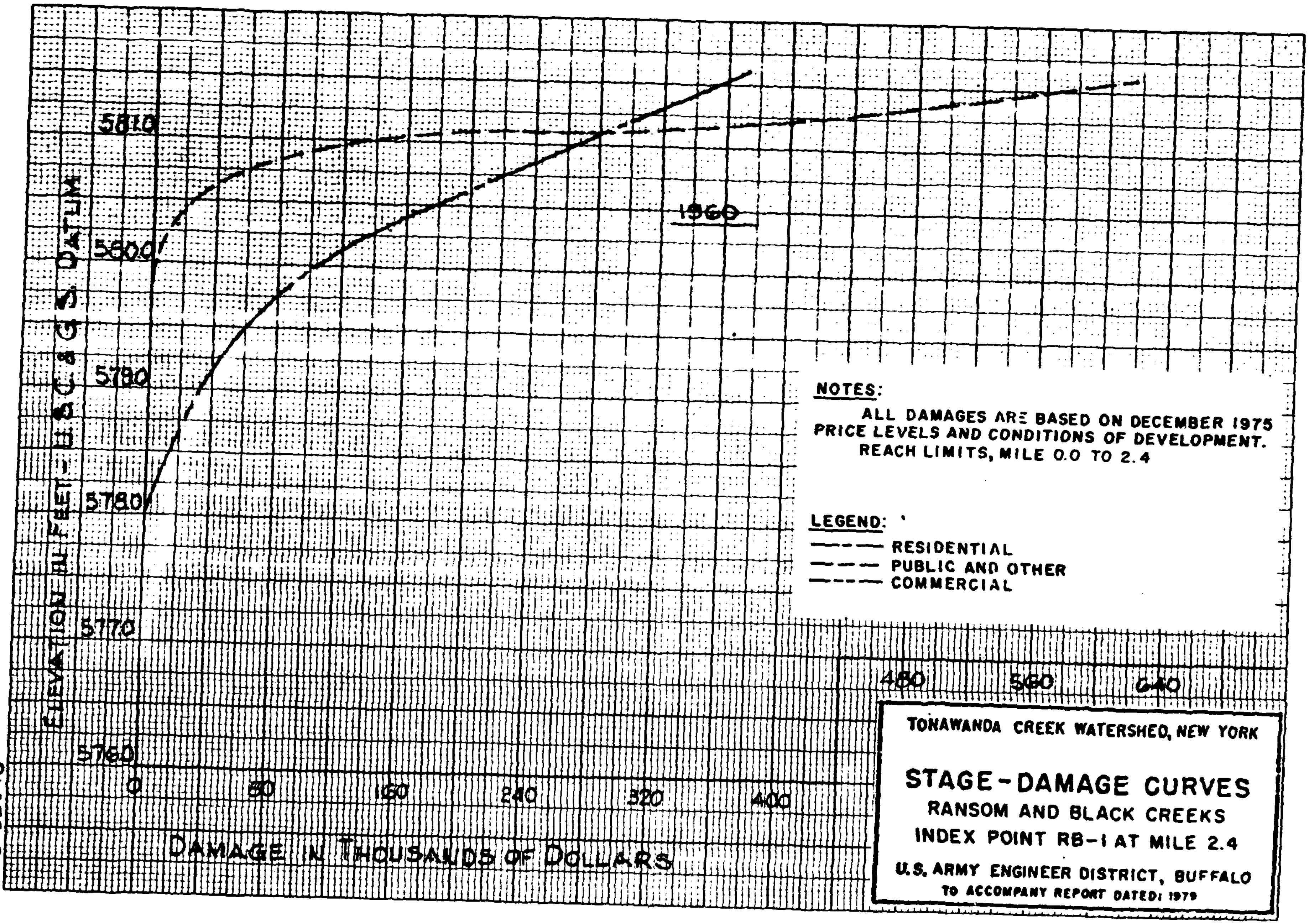


PLATE B25

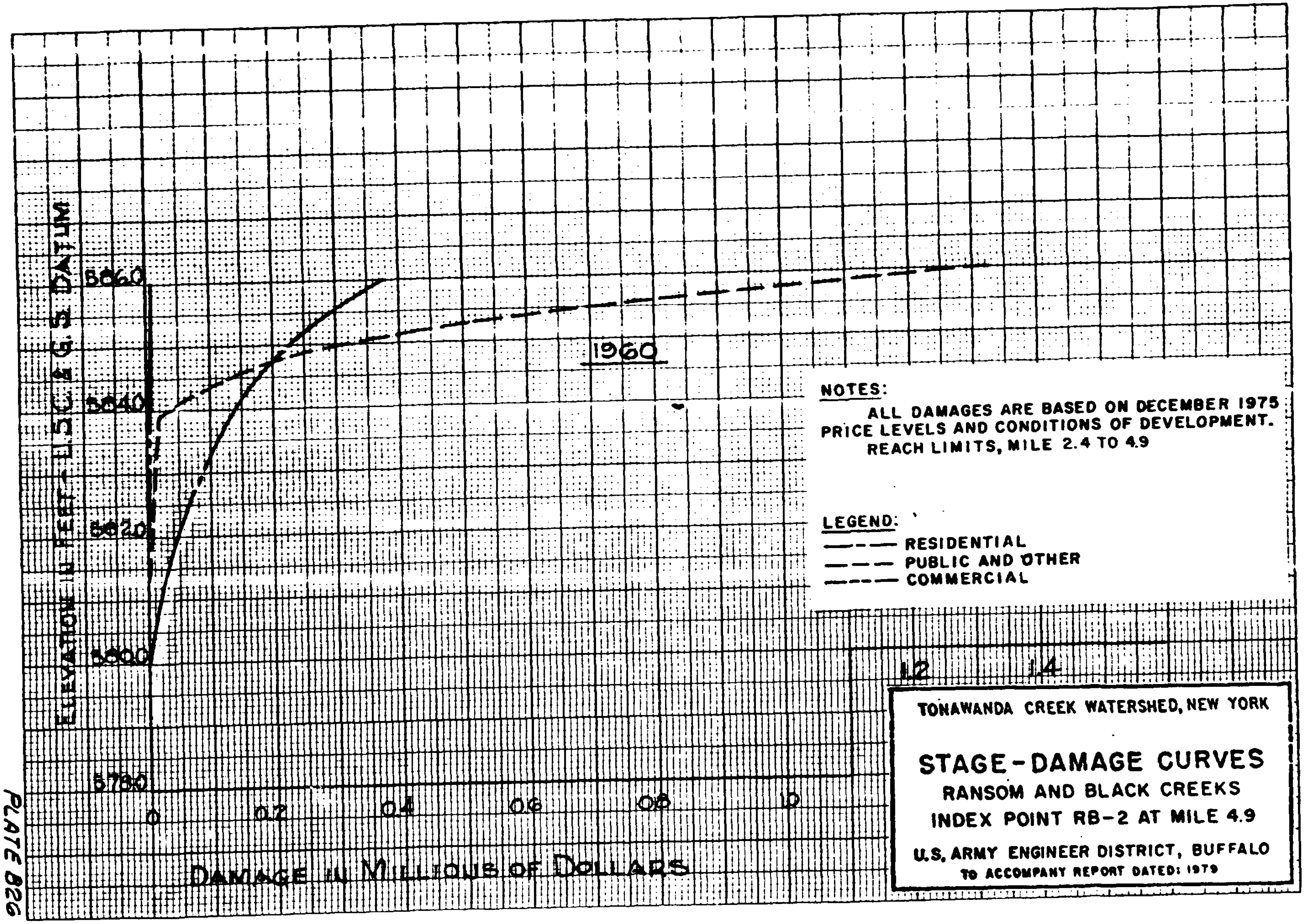
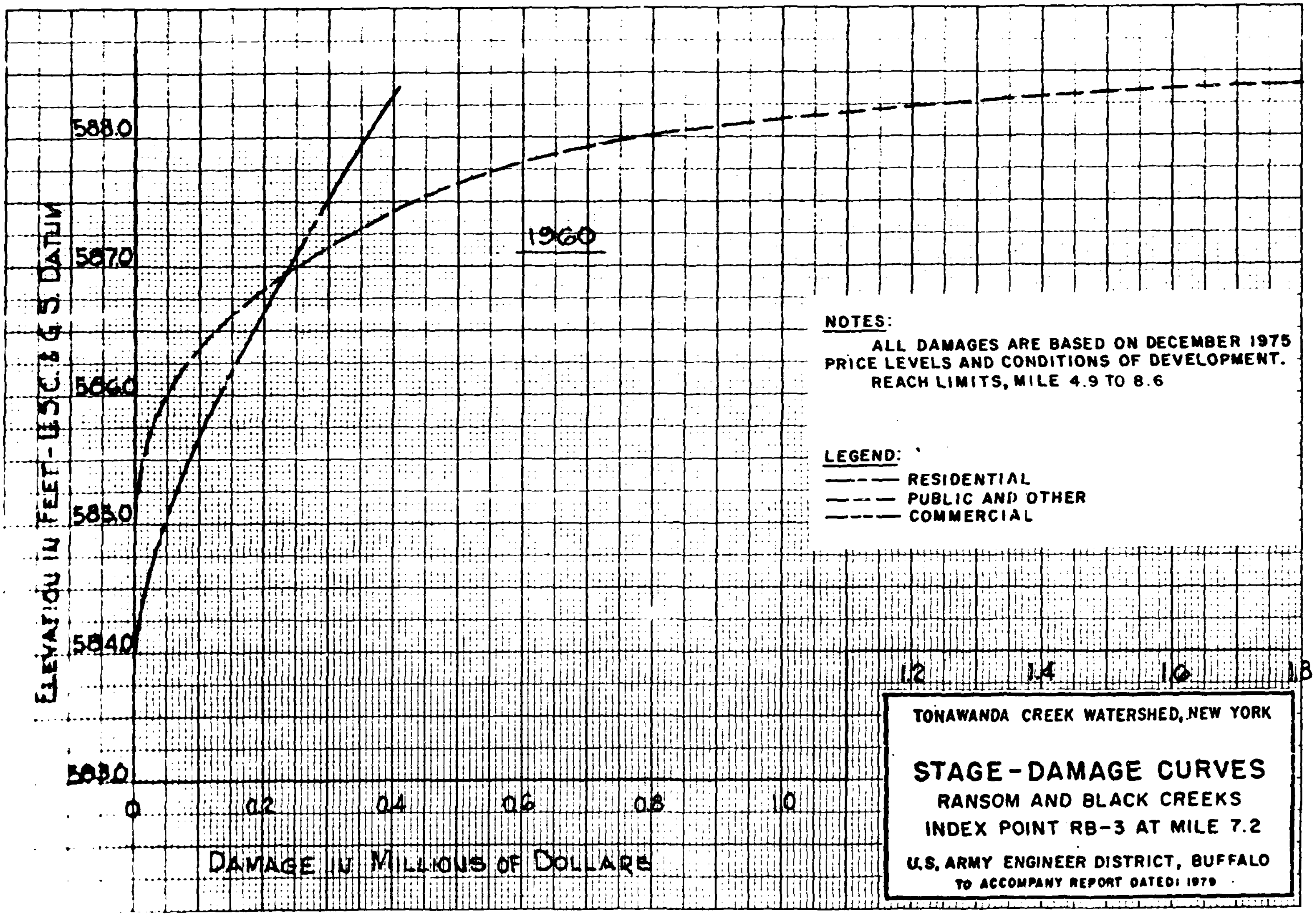

ELEVATION IN FEET - U.S.C. & G.S. DATUM
5860
5840
5820
5800
5780
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DAMAGE IN MILLIONS OF DOLLARS
1960
NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 2.4 TO 4.9
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE - DAMAGE CURVES
RANSOM AND BLACK CREEKS
INDEX POINT RB-2 AT MILE 4.9
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE B26

K•E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO.

46 1320



NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 4.9 TO 8.6

LEGEND:
---- RESIDENTIAL
---- PUBLIC AND OTHER
---- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES
RANSOM AND BLACK CREEKS
INDEX POINT RB-3 AT MILE 7.2

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

AD-A101 439 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2
BUFFALO METROPOLITAN AREA, NEW YORK WATER RESOURCES MANAGEMENT --ETC(U)
1980

UNCLASSIFIED NL

5 OF 8
AD A101439

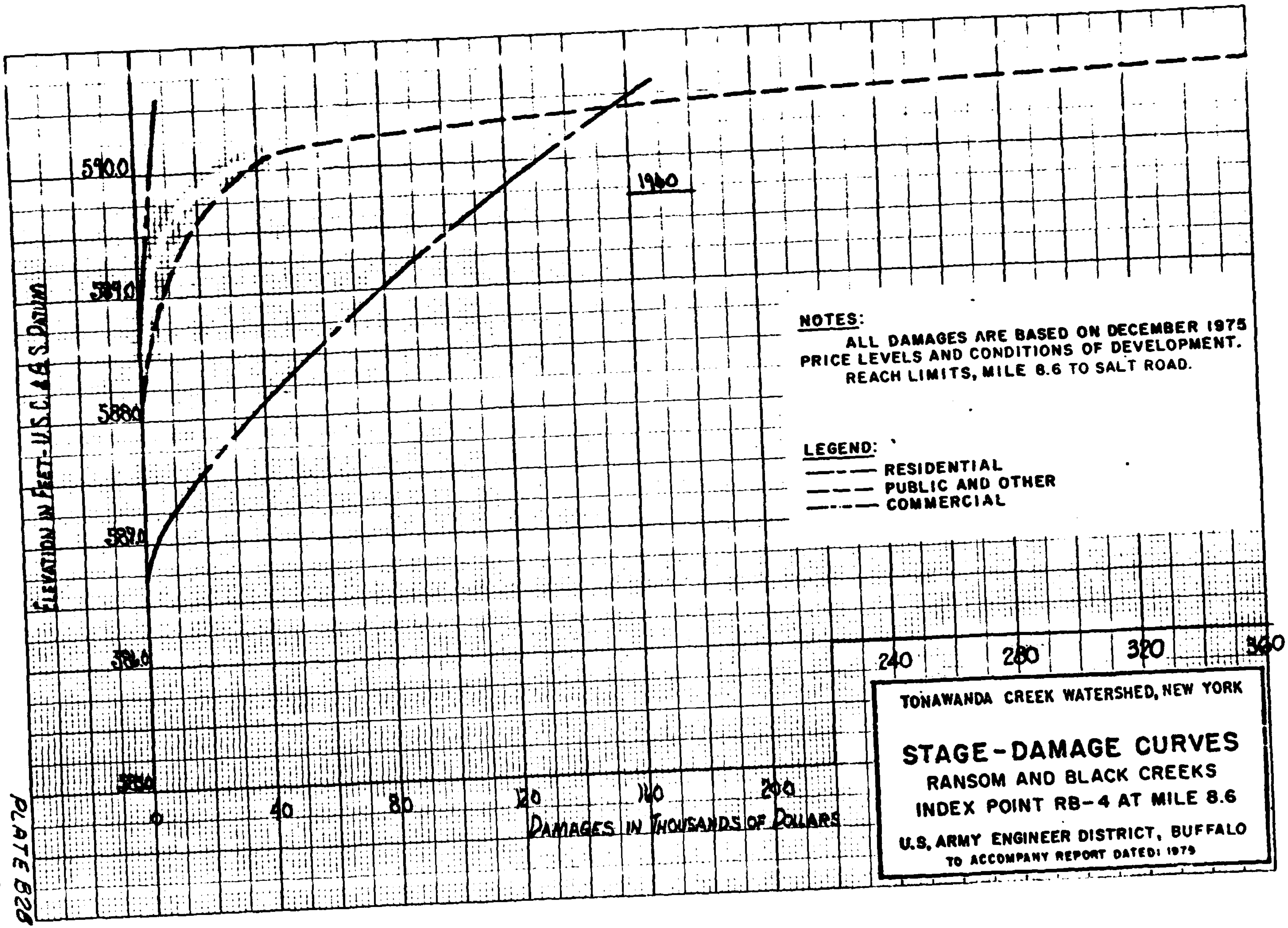
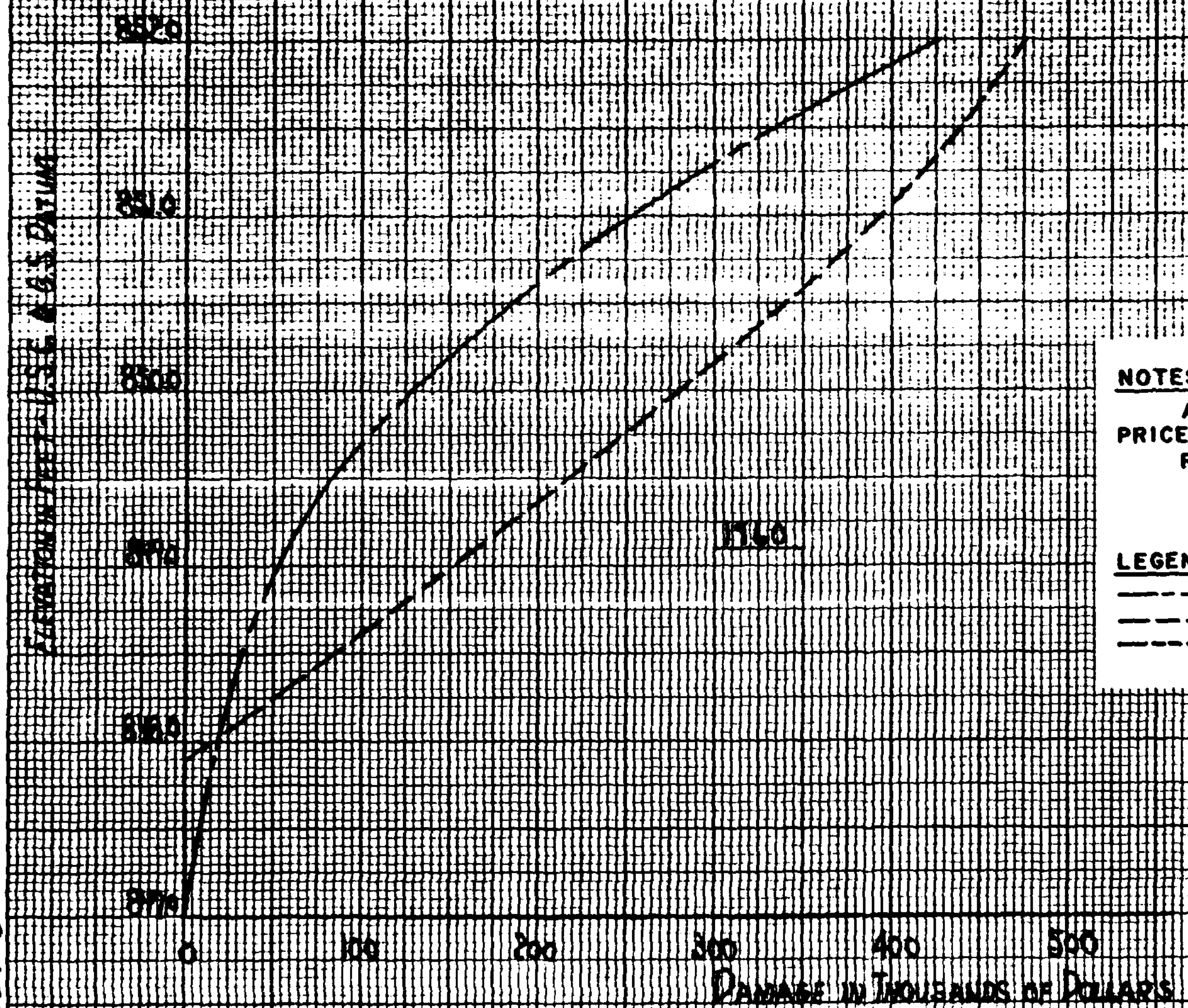

TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-DAMAGE CURVES
RANSOM AND BLACK CREEKS
INDEX POINT RB-4 AT MILE 8.6
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979
NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 8.6 TO SALT ROAD.
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
ELEVATION IN FEET - U.S.C. & G.S. DATUM
590.0
589.0
588.0
587.0
586.0
DAMAGES IN THOUSANDS OF DOLLARS
0
40
80
120
160
200
240
280
320
360
1960

PLATE B28



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 41.5 TO 59.5.

LEGEND:

- ——— RESIDENTIAL
- ——— PUBLIC AND OTHER
- ——— COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

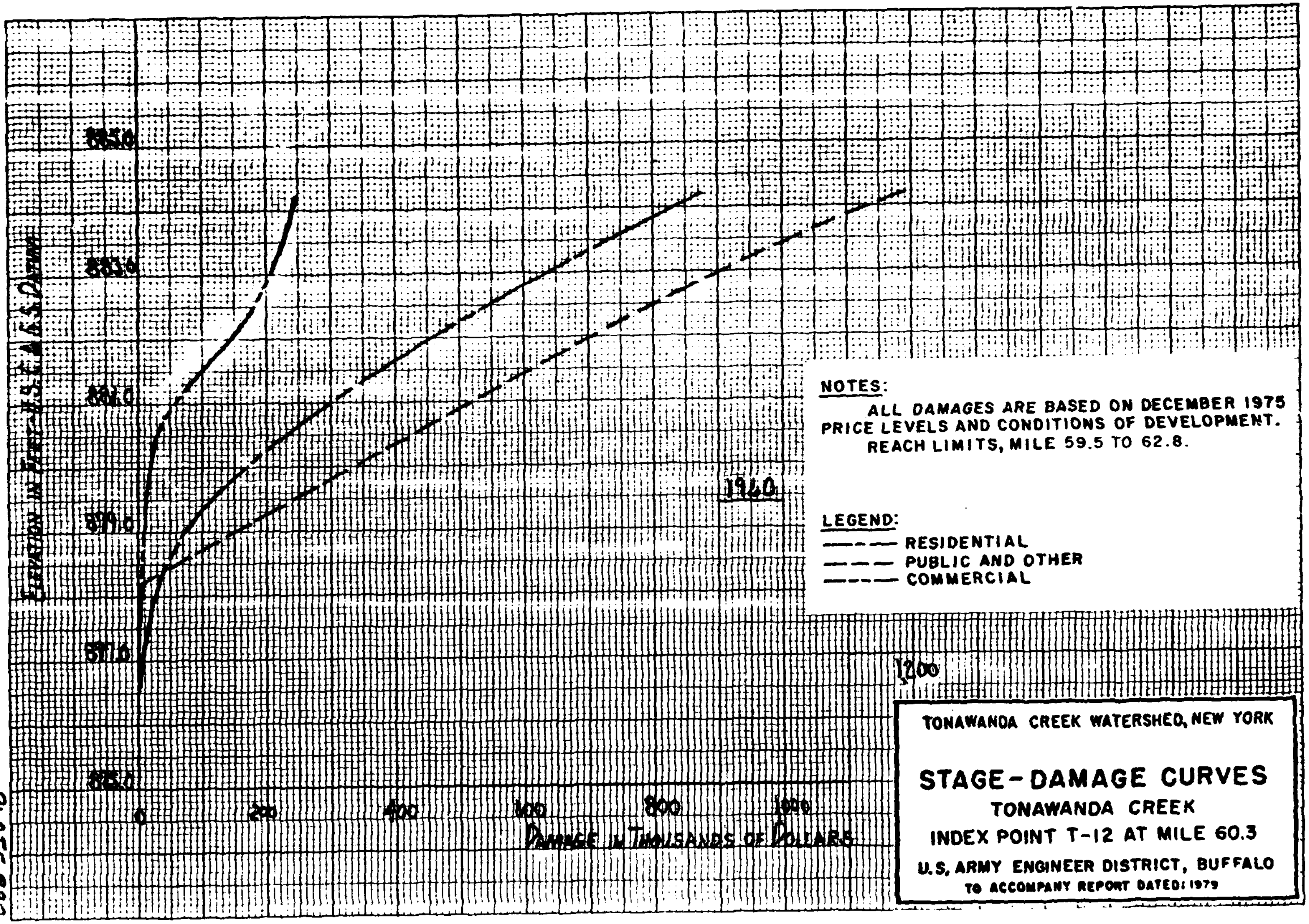
STAGE-DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT T-11 AT MILE 52.5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MILE 59.5 TO 62.8.

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES

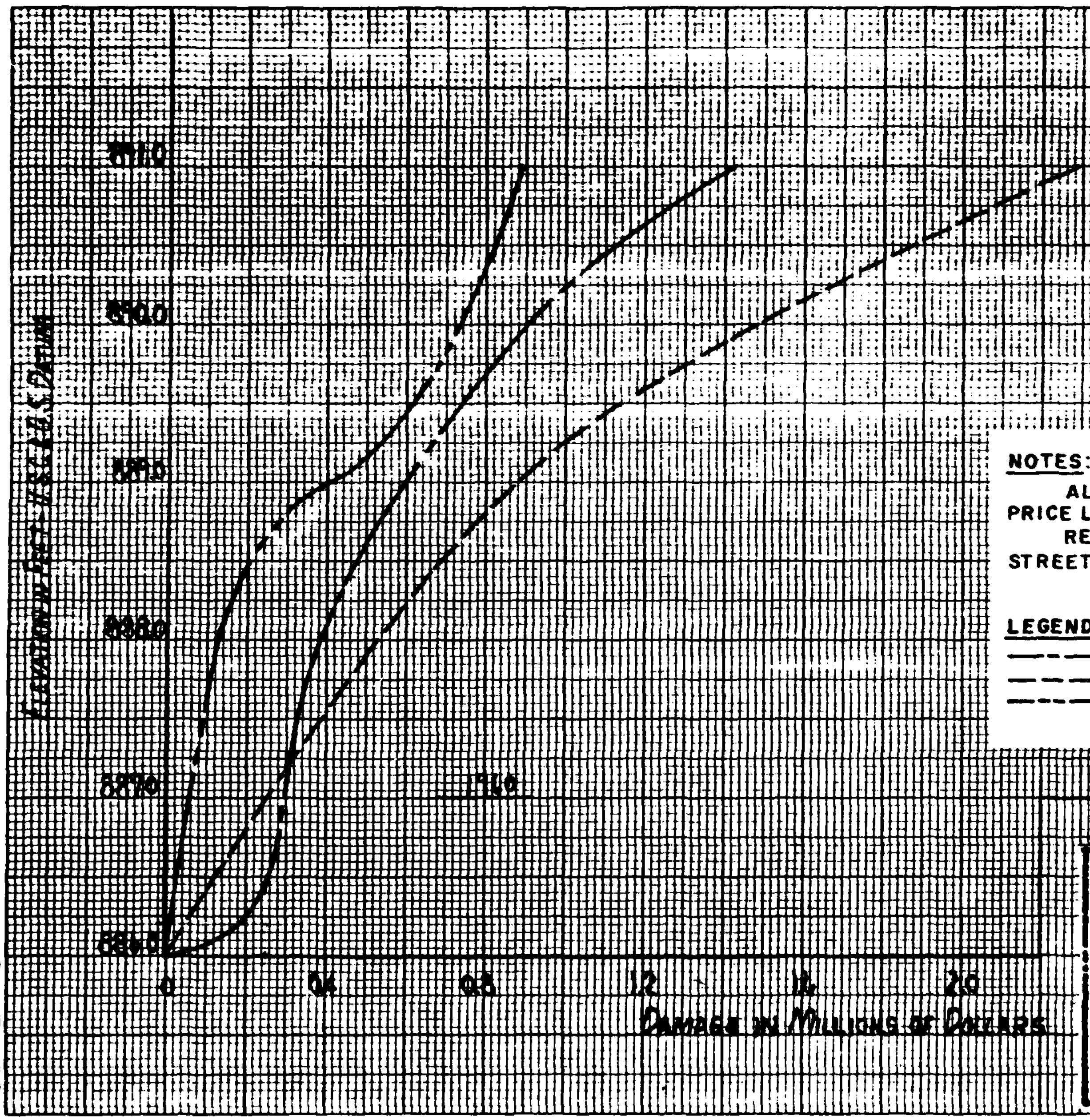
TONAWANDA CREEK

INDEX POINT T-12 AT MILE 60.3

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B30



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, WEST CITY LIMIT TO WALNUT STREET.

LEGEND:

- ——— RESIDENTIAL
- — — — PUBLIC AND OTHER
- —·—·— COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE – DAMAGE CURVES

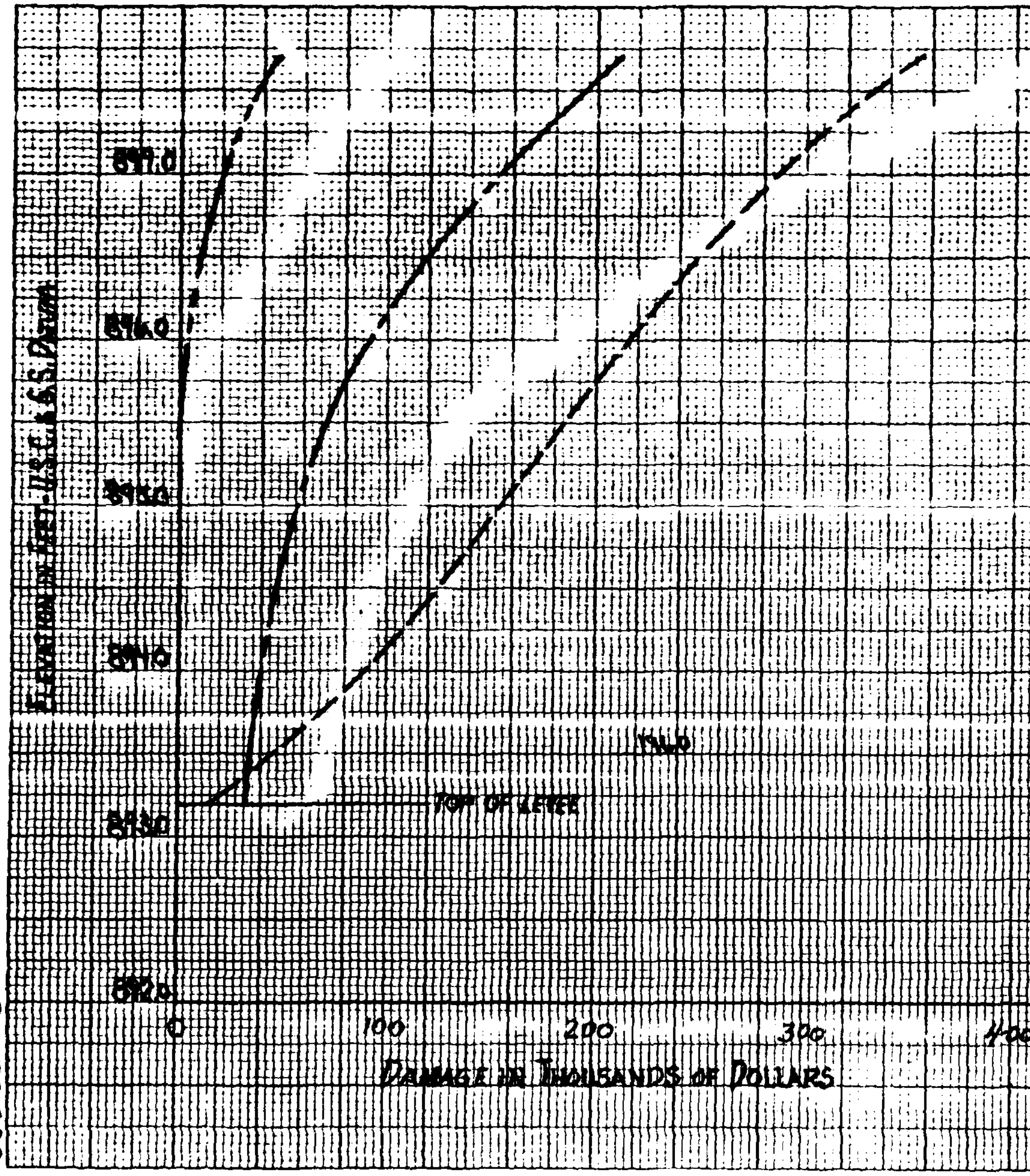
TONAWANDA CREEK

INDEX POINT B-1 AT MILE 63.4

UPSTREAM FACE OF SO. LYON ST. BRIDGE

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, WALNUT STREET TO LOWER PENN CENTRAL RAILROAD BRIDGE.

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

TONAWANDA CREEK

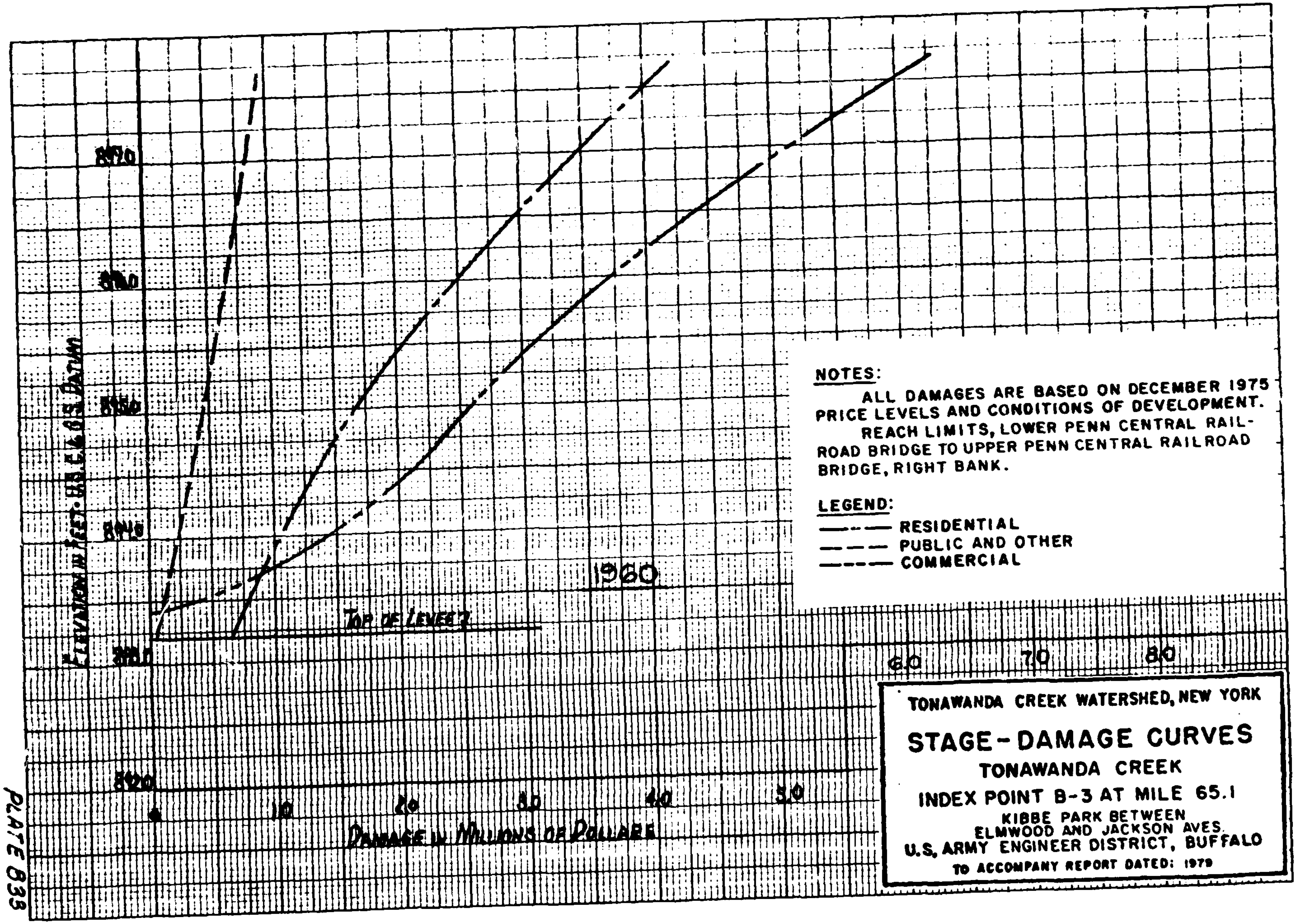
INDEX POINT B-2 AT MILE 65.1

KIBBE PARK BETWEEN ELMWOOD AND JACKSON AVES.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

K•E 10 X 10 TO ½ INCH KEUFFEL & ESSER CO. 46 1320



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, LOWER PENN CENTRAL RAILROAD BRIDGE TO UPPER PENN CENTRAL RAILROAD BRIDGE, RIGHT BANK.

LEGEND:

—·—·— RESIDENTIAL
— — — PUBLIC AND OTHER
—·—·— COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES

TONAWANDA CREEK

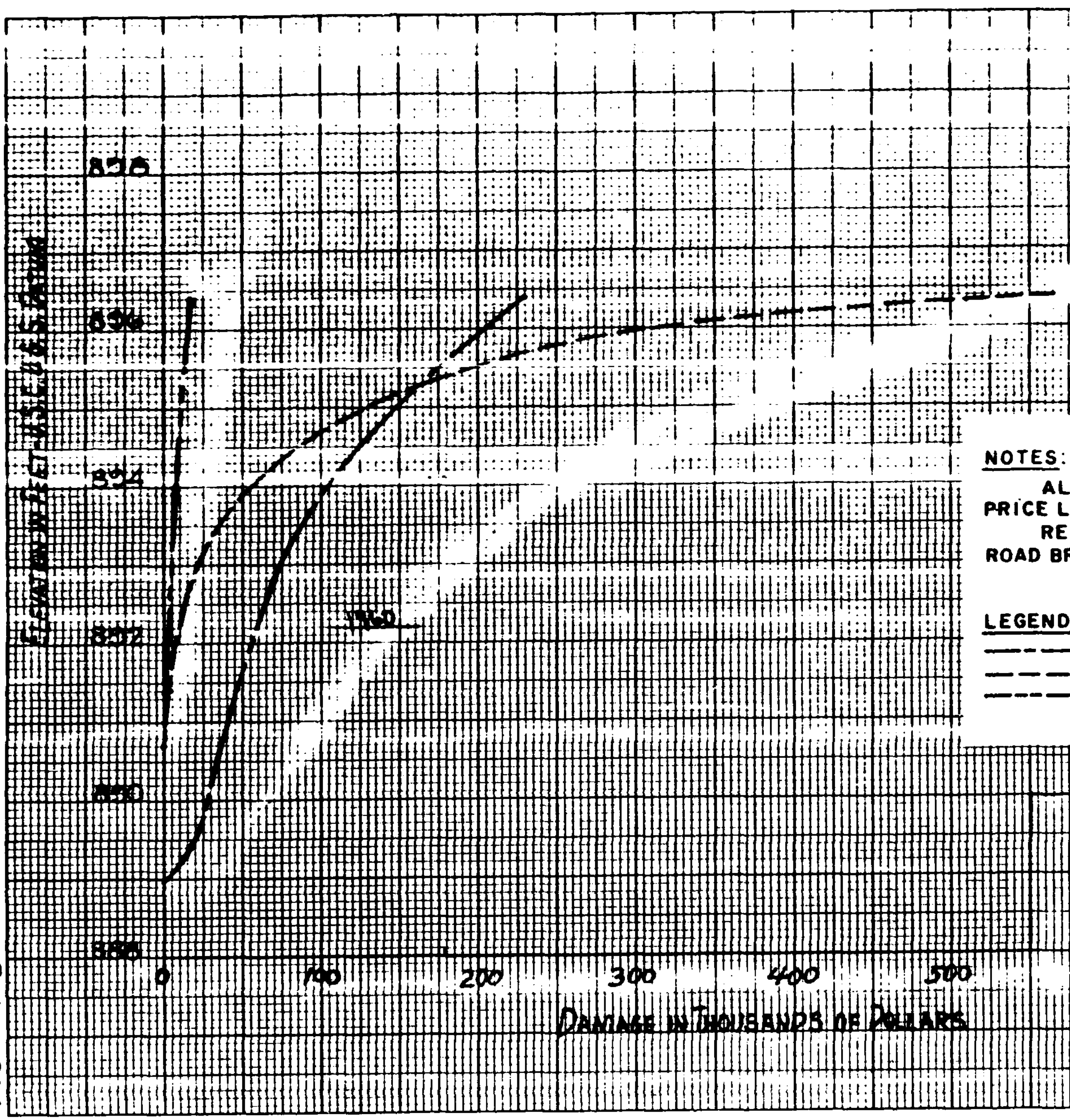
INDEX POINT B-3 AT MILE 65.1

KIBBE PARK BETWEEN ELMWOOD AND JACKSON AVES.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B33



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, LOWER PENN CENTRAL RAILROAD BRIDGE TO SOUTHERN CITY LIMIT LEFT BANK.

LEGEND:

- RESIDENTIAL
- PUBLIC AND OTHER
- COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT B-4 AT MILE 64.5

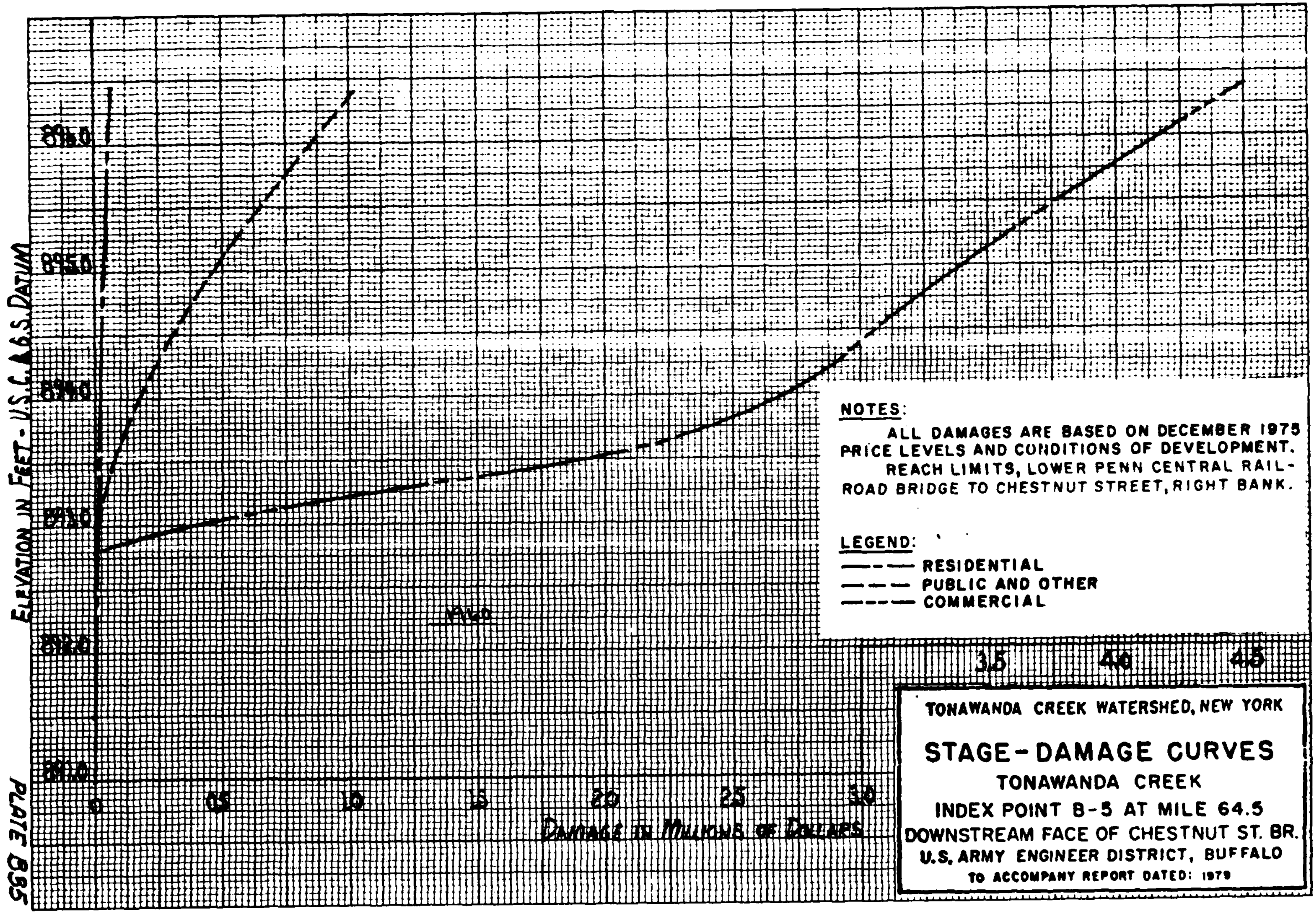
DOWNSTREAM FACE OF CHESTNUT ST. BR.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B34

K•E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, LOWER PENN CENTRAL RAILROAD BRIDGE TO CHESTNUT STREET, RIGHT BANK.

LEGEND:

— — — RESIDENTIAL
— — — PUBLIC AND OTHER
— — — COMMERCIAL

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

TONAWANDA CREEK

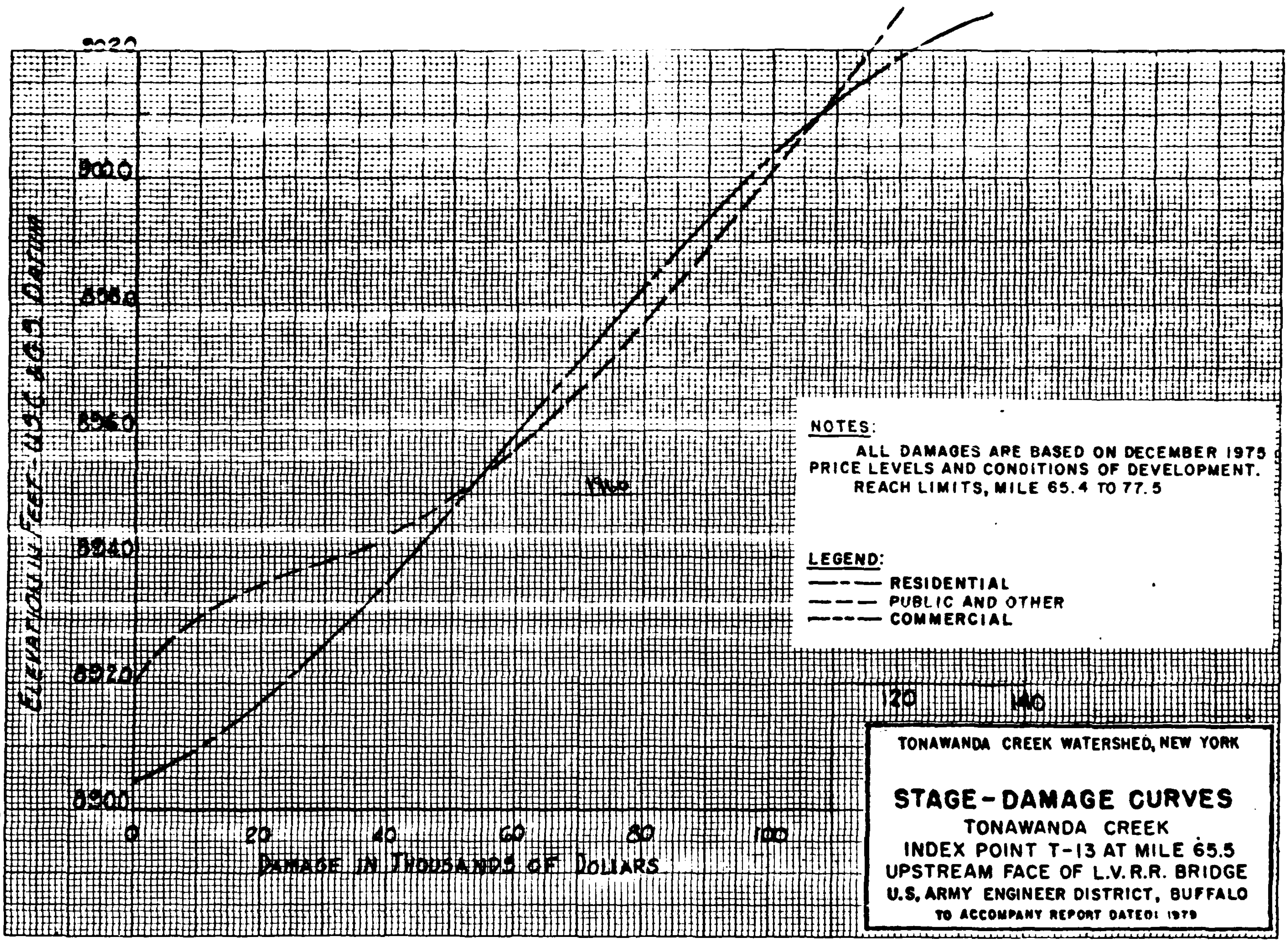
INDEX POINT B-5 AT MILE 64.5

DOWNSTREAM FACE OF CHESTNUT ST. BR.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

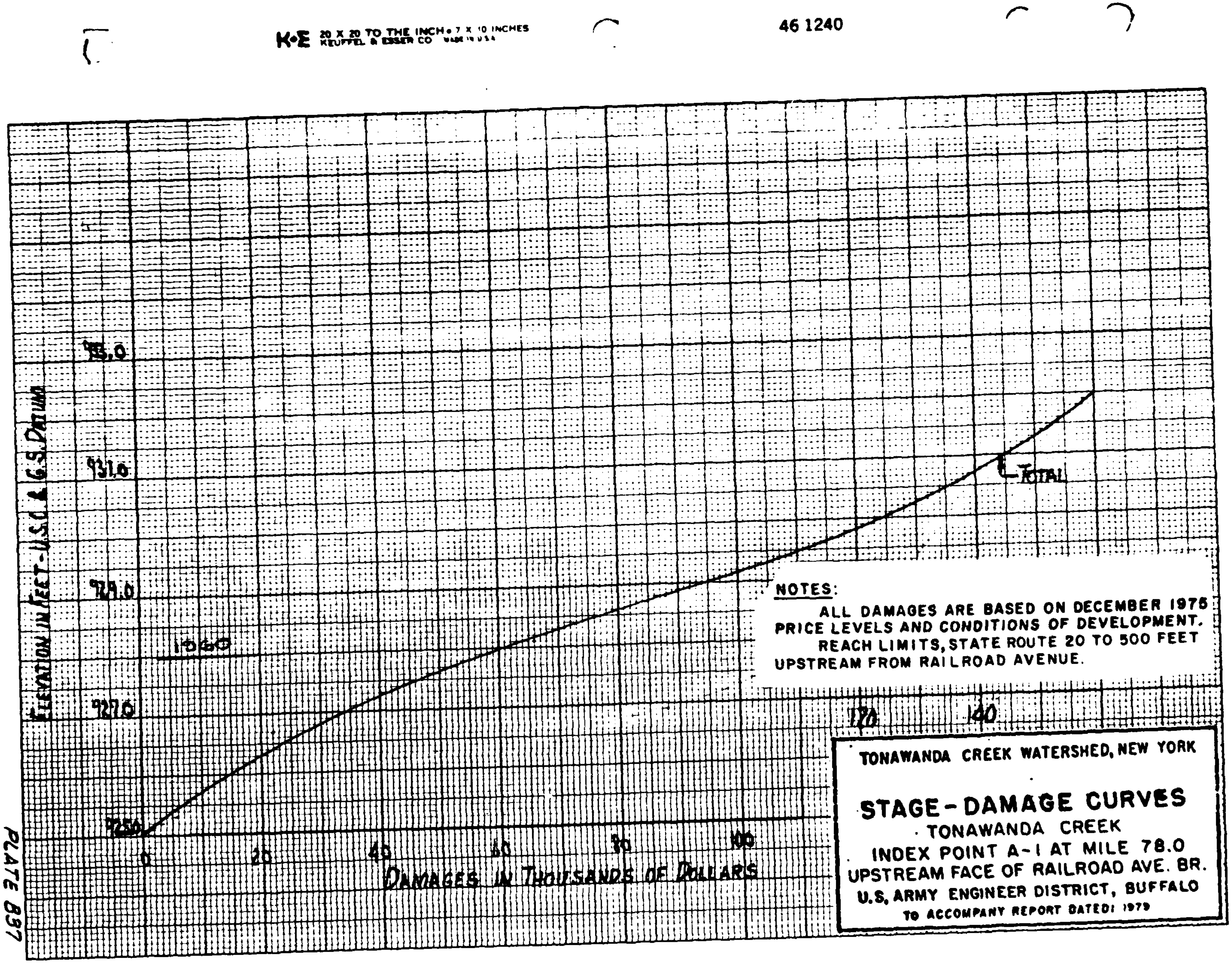
TO ACCOMPANY REPORT DATED: 1979

PLATE B35



ELEVATION IN FEET - USC&GS DATUM
DAMAGE IN THOUSANDS OF DOLLARS
0
20
40
60
80
100
120
140
NOTES:
ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.
REACH LIMITS, MILE 65.4 TO 77.5
LEGEND:
RESIDENTIAL
PUBLIC AND OTHER
COMMERCIAL
TONAWANDA CREEK WATERSHED, NEW YORK
STAGE-DAMAGE CURVES
TONAWANDA CREEK
INDEX POINT T-13 AT MILE 65.5
UPSTREAM FACE OF L.V.R.R. BRIDGE
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1979

PLATE B36



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, STATE ROUTE 20 TO 500 FEET UPSTREAM FROM RAILROAD AVENUE.

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE-DAMAGE CURVES

TONAWANDA CREEK

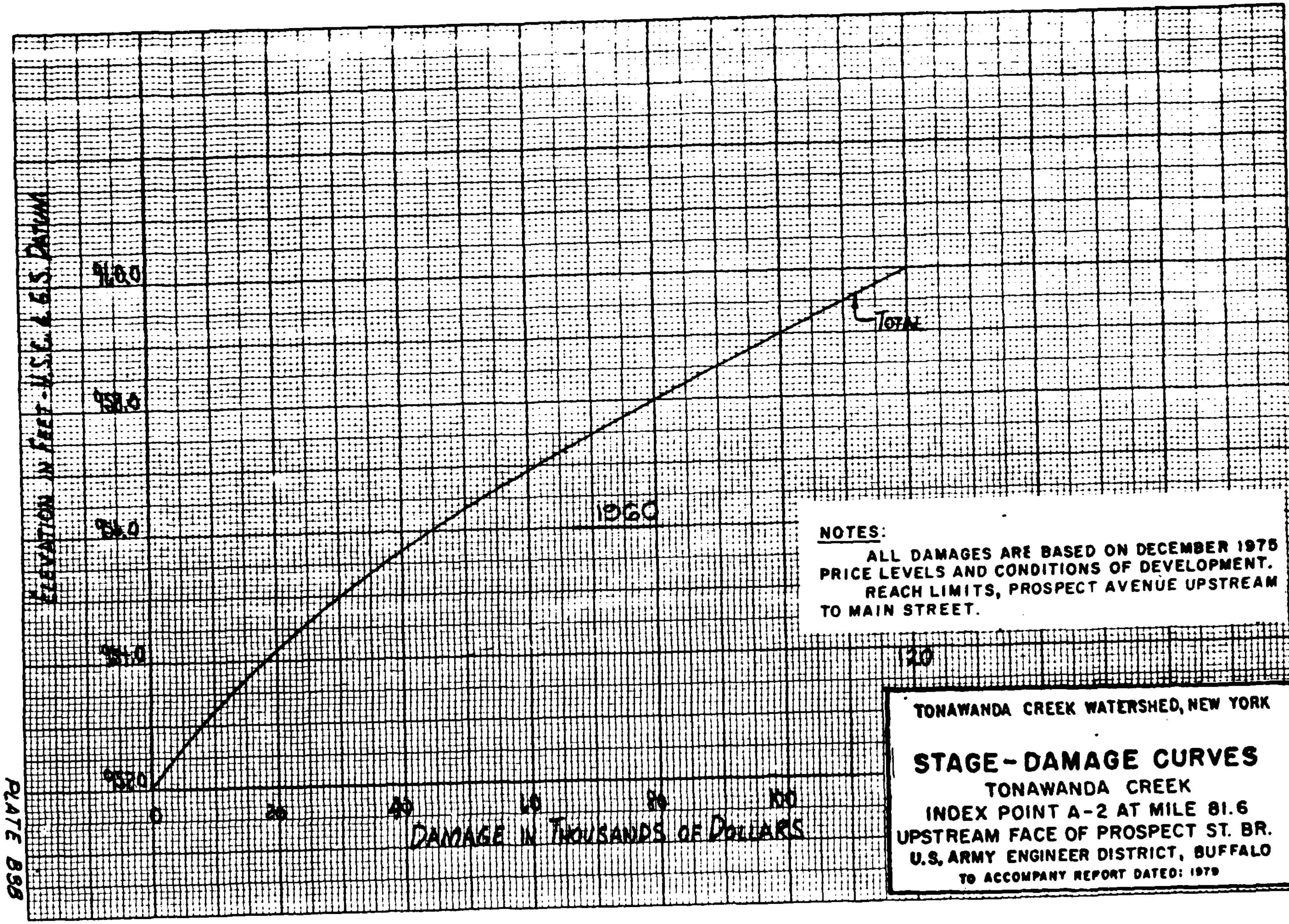
INDEX POINT A-1 AT MILE 78.0

UPSTREAM FACE OF RAILROAD AVE. BR.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

PLATE B37



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, PROSPECT AVENUE UPSTREAM TO MAIN STREET.

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

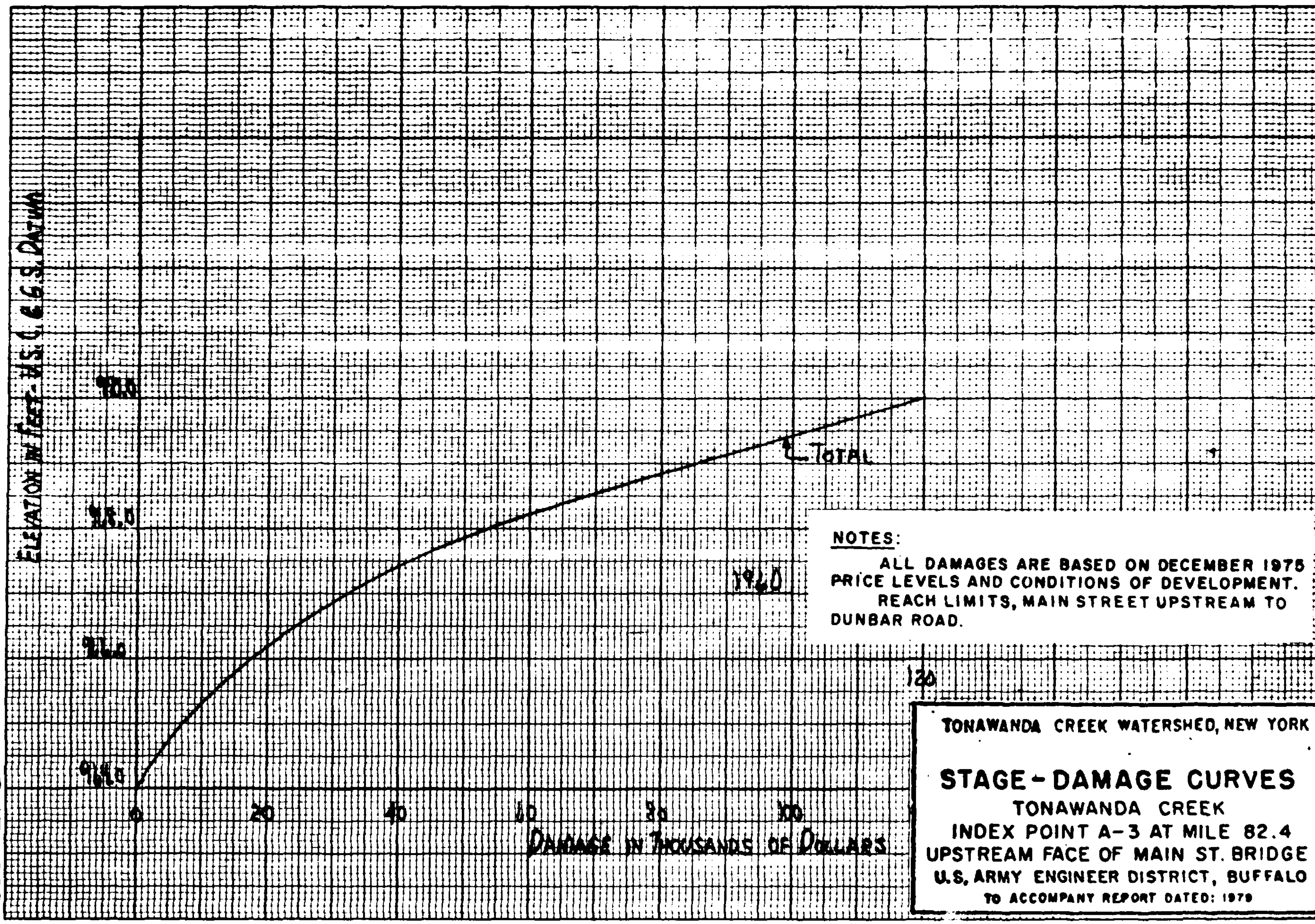
TONAWANDA CREEK

INDEX POINT A-2 AT MILE 81.6

UPSTREAM FACE OF PROSPECT ST. BR.

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979



NOTES:

ALL DAMAGES ARE BASED ON DECEMBER 1975 PRICE LEVELS AND CONDITIONS OF DEVELOPMENT.

REACH LIMITS, MAIN STREET UPSTREAM TO DUNBAR ROAD.

TONAWANDA CREEK WATERSHED, NEW YORK

STAGE - DAMAGE CURVES

TONAWANDA CREEK

INDEX POINT A-3 AT MILE 82.4

UPSTREAM FACE OF MAIN ST. BRIDGE

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1979

BUFFALO METROPOLITAN AREA, NY
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

ECONOMIC SUPPLEMENT TO APPENDIX B

FLOOD DAMAGE

AND

MANAGEMENT BENEFITS

FOR THE

BATAVIA RESERVOIR COMPOUND - MODIFIED

U. S. Army Corps of Engineers
Buffalo District

ECONOMIC SUPPLEMENT TO APPENDIX B

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TABLE OF CONTENTS (Cont'd)

TABLES OF CONTENTS (Cont'd)

PLATES

FACT SHEET

Project Interest Rate	7-3/8 percent
Project Evaluation Period	1985-2035
Price Level	June 1980
Conditions of Development	1985
Project Economists	Jack Carr, Economist Ray Waxmonsky, Economist Ron Guido, Chief, Economics Section
Selected Plan	Batavia Reservoir Compound - Modified (BRCM)
Average Annual Benefits	$2,617,500
Average Annual Costs	2,043,000
Net Benefits	574,500
Benefit-Cost Ratio	1.28
Sensitivity Analysis	Upper Reservoir Only
Average Annual Benefits	$1,979,770
Average Annual Costs	1,335,000
Net Benefits	644,770
Benefit-Cost Ratio	1.48

S1. PREFACE

Major changes have been made to the 1976 Final Feasibility Report, primarily in the areas of the recommended operating plan of the Batavia Reservoir Compound. Benefits have been escalated to June 1980 price levels and the project interest rate has increased to 7.375 percent since the preparation of the initial feasibility study in November 1976.

The objectives of the Economic Supplement to the Revised Final Feasibility Report are: to present more detailed estimates of damages and benefits to farm operators within the immediate project site and to urban development in downstream reaches of the watershed; to reflect the impact of revised hydrology in terms of existing and improved stage frequency curves and average annual damages; and to verify the current potential for short and long-term development of floodprone areas as it relates to E.O. 11988.

The Selected Plan from the 1976 report in this Economic Supplement is referred to as the Batavia Reservoir Compound - Modified (BRCM). Reach T-13 has been subdivided into an upper portion, which includes the area above the upper reservoir alignment upstream to Railroad Avenue in Alexander, NY, and a lower portion which includes the area above the alignment of the lower reservoir upstream to a point immediately below the emergency spillway of the upper reservoir. This subdivision was required to develop detailed estimates of agricultural damages and benefits to existing farm units from the operation of a reservoir compound and to quantify future benefits as a result of changes in crop distributions.

A general sensitivity study was also conducted for the construction of the upper reservoir component only. This investigation concluded that an upper reservoir only would require a commitment of less economic resources but would also produce fewer average annual benefits and less protection for downstream reaches in the watershed.

Agricultural statistics developed during the preparation of the Economic Supplement have been coordinated with the Cooperative Extension Service, U. S. Department of Agriculture, and the Genesee County Soil and Water Conservation District. Representatives of both agencies have indicated that construction of the Selected Plan would provide positive economic long-term benefits to the watershed.

S2. AGRICULTURE

S2.1 General Agricultural Characteristics

The agricultural component of this Supplement is substantially revised from the agricultural analysis in the 1976 Final Feasibility Report. The information contained in this Supplement is based upon a survey conducted in summer 1978 of agriculture in the flood plain. (Tonawanda Creek Watershed, Agricultural Activity Study, Supplemental Report, prepared by Wendel Engineers and RECRA Research for the Buffalo District Office, Corps of Engineers, 1978). This information was based upon field investigations of flood plain land use; interviews with farm operators and local agricultural authorities, and a review of secondary data sources that included Cornell University, the Census of Agriculture, and publications of normalized price standards developed by the Water Resources Council.

a. Agricultural Land Use. Agricultural land use within the flood plain, the area that could be inundated by the Standard Project Flood, was estimated from field surveys and interviews conducted in August 1978. The resulting pattern of crop distributions within this flood zone, which are presented in tabular form in Table S1, were mapped and checked against land use maps developed by New York State in 1968 which served as a secondary source or bench mark for basin-wide land use inventories.

It is estimated that 19,065 acres were devoted to agriculture on the flood plain in 1978. Of this total, 15 percent (2,950 acres) was not cropped. This includes land which is not used for any of the crops listed in Table S1, but which had been in production in 1968 when the LUNR mapping was conducted. The remaining 85 percent (16,115 acres) was distributed among eight major crop categories: corn for silage, corn for grain, wheat (winter), oats, buckwheat, hay, pasture, and miscellaneous cash crops. Grouping these crops produces four aggregated crop categories which are characteristic of a dairy farming region such as the Tonawanda Creek Watershed. These four aggregate crop categories are: corn for silage; forage crops (hay and pasture); cash field crops (oats, wheat, buckwheat, and corn for grain), and miscellaneous cash crops (a variety of small vegetables, sod, flowers, strawberries, and other such crops). Corn for silage was the largest component of total agricultural land and it accounted for 32 percent of total agricultural lands. Forage crops for dairy cattle and cash field crops each accounted for another 24 percent of total agricultural land use, miscellaneous cash crops accounted for five percent, and idle land accounted for the remaining 15 percent. It is assumed that land devoted to agriculture will remain relatively static and that 1978 conditions of development will approximate 1980 conditions.

b. Crop Yields. Table S2 presents estimated crop yields for the principal crops grown on the flood plain in 1978. It should be noted that these yields reflect existing conditions which are depressed in comparison to yields obtained elsewhere. Some examples of this include: (1) the yield for corn produced as a grain (65.2 bushels per acre) is below the national average yield (104 bushels per acre), and (2) the yield of oats (47.1 bushels per acre) and wheat (31 bushels per acre) are below the national average yield per acre (data from: 1978 Economic Reanalysis of Roseau River Project, St. Paul District Office, U. S. Army Corps of Engineers). It is estimated

Table S1 - Distribution of Crops, by Acre

Crop Reach	Corn-Silage	Corn-Grain	Wheat	Oats	Buck-Wheat	Hay	Pas-ture	Misc 1/	Idle	Total
T-3	70			25	10	10		215	30	360
T-4	60	15	30	60		270	70			505
T-5	620	30	20	60	180	210	50	70	150	1,390
T-6	700	10	230	520		470	50		100	2,080
T-7	390		70	150	70	375			370	1,425
T-8	540			400	340	270			320	1,870
T-9	350		250	50	40	105			300	1,095
T-10					N E G L I G I B L E					
RB-1	40				20			20	60	140
RB-2	90		30		20	40		80	50	310
RB-3	60		30			340	100	345		875
RB-4	10			60		110		70		250
M-1	100						50			150
M-2	200				170	50				420
M-3	550			300		200	20			1,070
M-4	200		60				30			290
M-5	450		150	100	100	250				1,050
M-6	450		400			150				1,000
T-11	120	80	40	NEG	20	20	170	NEG	195	645
T-12	40	15	NEG				40	80	45	220
T-13 Lower	765	190	160	40	70	110	825	NEG	950	3,110
T-13 Upper	220	40	15	NEG	10	25	70	NEG	320	700
A-1, 2, 3	40	10	NEG	-	-	-	-	-	60	110
Total	6,065	390	1,485	1,765	1,050	3,005	1,475	880	2,950	19,065
Per-cent	32	2	8	9	5	16	8	5	15	100

1/ Negligible amounts of other crops are indicated for each reach where appropriate.

Source: Table III-1, Tonawanda Creek Watershed Agricultural Activity Study Supplemental Report prepared by RECRA Research, Inc. & Wendel Engineers.

that current yields on the Tonawanda Creek flood plain are 40 to 70 percent below that being achieved by farmers in the watershed but located off the flood plain.

Table S2 - Crop Yields of Principal Crops Grown on the Flood Plain in 1978 1/

Crop	Yield/Acre
Corn, silage	11.4 tons
Corn, grain	65.2 bushels
Oats	47.1 bushels
Hay, mixed	2.5 tons
Winter Wheat	31.0 bushels
Buckwheat	12.5 hundredweight

1/ Weighted average yields reflect distribution of and crop yields for Genesee silt loam and Canandaigua soil types.

c. Crop Prices. Because of wide annual fluctuations in crop prices, prices used in this report are the normalized values provided by the Water Resources Council. Crops not surveyed by the WRC, corn for silage, buckwheat, and winter wheat are based upon an average price received by local farmers for the last 3 years. These prices are provided in Table S3.

Table S3 - Prices of Principal Crops Grown on the Tonawanda Creek Flood Plain

Crop	1976 Normalized Price 1/
	$
Corn, silage	19.00 per ton
Corn, grain	2.52 per bushel
Hay, mixed	48.78 per ton
Wheat, winter	3.15 per bushel
Oats	1.65 per bushel
Buckwheat	8.00 per hundredweight

1/ U. S. Water Resources Council, Agricultural Price Standards Oct. 1977.

d. <u>Farm Schedules</u>. The monthly schedules of farm operations (Tables S4 through S9) present data on variable production costs for agriculture on the flood plain for each of the six principal crops grown on the flood plain: corn for silage, corn for grain, mixed hay, winter wheat, oats, and buckwheat. These costs were obtained through interviews of flood plain farmers by the agricultural consultant. Only variable production costs are considered because fixed costs are not significantly affected by floods in the short run and because they would be incurred irrespective of whether or not a crop is produced. Because a sizable amount of cultivated land is rented, land rent has been treated as a variable production cost. Variable production costs include expenditures for: land rent, land preparation, seed, fertilizer, planting, weed/pest control, drainage, irrigation, cultivation, and harvest.

Table S8 presents the schedule of farm activities, variable production costs, gross revenue, and crop loss for oats. Since oats is a summer crop, farming activities commence in April and are completed in August; thus there are no entrees in the months of January through March, September through December (the nongrowing season for oats). For any one month, the subtotal "Monthly Increment" summarizes all variable production costs expended. For April, the sum of all variable production costs expended is $39 (land rent $20, land preparation $10, seed $5, planting $4). Since $39 is expended in April, this amount is entered as "Expended Variable Production Costs" for the month. "Unexpected Variable Production Costs" are calculated by subtracting "Expended" from "Total Variable Production Costs"; $39 subtracted from $85 produces $46 of Unexpended Variable Production Costs in April (actually, as of 30 April). "Total Variable Production Costs" are the sum of all variable production costs involved in producing the crop throughout the crop's growing season (April through August for oats); these are entered as the last column of the table. For oats, this amounts to $85: land rent $20, land preparation $10, seed $10, fertilizer $14, planting $8, weed/pest control $5, and harvest $18. Gross revenue for oats ($78) is the product of crop yield (47.1 bushels per acre, Table S2), and crop price ($1.65 per bushel, Table S3).

Besides presenting data on variable production costs, the farm schedules provide monthly estimates of crop loss. The concept of crop loss used in this study is gross profit foregone plus expended variable production costs. Though this is a reasonably simple concept, the calculation of crop loss in this manner becomes a little more complex than necessary as it involves calculating an additional value, gross profit. Since it may be shown that gross profit per acre plus expended variable production costs per acre is identical to gross revenue per acre minus unexpended variable production costs per acre, and since the latter is simpler than the former, crop loss is calculated in Tables S4 through S9 as gross revenue per acre minus unexpended variable production costs.

Calculation of the monthly crop loss for oats (Table S8) is based upon the following methodology. "Gross Revenue" per acre ($78) is entered in every month of the crop's growing season as an accounting procedure even though this amount is only realized at the end of the season when the oats are harvested. "Unexpended Variable Production Costs," which are $46 per acre at the end of April, decrease as the growing season progresses (as expended variable production costs increase). "Unexpended Variable Production Costs"

decrease to $24 by the end of May; in June they drop to $18, and by August they have decreased to $0, when all production costs have been expended. "Crop Loss," which is defined as the difference between "Gross Revenue" and "Unexpended Variable Production Costs," increases from $32 in April to $55 in May, to $60 in June and July, and $78 in August.

Agricultural damages are based upon a weighted average value of the potential agricultural loss per acre of cropland in each reach. This required an estimate of the average monthly seasonal loss value per acre of cropland for each of the principal crops. However, since the majority of historical floods have occurred during the period from November to April, the average loss calculated is that which would occur for each crop over the six-month period of the "nongrowing" season. For winter wheat, for example (see Table S7), the sum of the loss value for the period November through April, ($75, $75, $75, $75, $75, and $80) is summed ($455) and that value is divided by six to estimate the average monthly loss ($75.83 per acre) for winter wheat.

Miscellaneous crops is a category of several individual crops, none of which is very prominent on the flood plain, but which together account for 5 percent of the cultivated land. Included in this category are: sweet corn, alfalfa, seed for hay crops, sod (grass), cut flowers, and a variety of small vegetables (potatoes, cabbages, beets, broccoli, carrots, etc.).

Table S4 - Monthly Schedule of Farm Activities, Production Costs, Revenue and Crop Loss Values: CORN SILAGE (1976 dollars per acre)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Variable Production Costs													
Land Rent					20								20
Land Preparation					13								13
Seed					10								10
Fertilizer					20	18							38
Planting					4								4
Weed/Pest Control					13								13
Drainage													
Irrigation													
Cultivation						5							5
Harvest									12	12			24
Monthly Increment					80	23			12	12			
Accumulated Cost					80	103	103	103	115	127			
Total Variable Production Costs					127	127	127	127	127	127			127
Expended					80	103	103	103	115	127			
Unexpended					47	24	24	24	12	0			
Gross Revenue					217	217	217	217	217	217			217
Crop Loss 1/					170	193	193	193	205	217			

1/ Gross revenue minus unexpended variable production costs.

Table S5 - Monthly Schedule of Farm Activities, Production Costs, Revenue and Crop Loss Values: CORN GRAIN (1976 dollars per acre)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Variable Production Costs													
Land Rent					20								20
Land Preparation					13								13
Seed					10								10
Fertilizer					20	18							38
Planting					4								4
Weed/Pest Control					13								13
Drainage													
Irrigation													
Cultivation						5							5
Harvest										18			18
Monthly Increment					80	23				18			
Accumulated Cost					80	103	103	103	103	121			
Total Variable Production Costs					121	121	121	121	121	121			121
Expended					80	103	103	103	103	121			
Unexpended					41	18	18	18	18	0			
Gross Revenue					164	164	164	164	164	164			164
Crop Loss 1/					123	146	146	146	146	164			

1/ Gross revenue minus unexpended variable production costs.

Table S6 - Monthly Schedule of Farm Activities, Production Costs, Revenue and Crop Loss Values: MIXED HAY (1976 dollars per acre)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Variable Production Costs													
Land Rent				20									20
Land Preparation				4									4
Seed				8									8
Fertilizer				8									8
Planting													
Weed/Pest Control													
Drainage													
Irrigation													
Cultivation													
Harvest					25		21		17				63
Monthly Increment				+40	25		21		17				
Accumulated Cost				+40	65	65	86	86	103				
Total Variable Production Costs	103	103	103	103	103	103	103	103	103	103	103	103	103
Expended	103	103	103	40	65	65	86	86	63	103	103	103	103
Unexpended	0	0	0	63	38	38	17	17	0	0	0	0	0
Gross Revenue	122	122	122	122	122	122	122	122	122	122	122	122	122
Crop Loss	122	122	122	59	84	84	105	105	122	122	122	122	
Adjusted Crop Loss	18	18	18	9	13	13	16	16	18	18	18	18	

Notes:
1. Land preparation, seed, and half of fertilizer costs ($4) are undiscounted average annual costs expended in each year of the crops' average life; land rent, half of fertilizer costs ($4), and harvesting are annual costs actually expended and each year.
2. Half of the fertilizer cost ($4) represents an undiscounted average annual cost of top dressing the crop once in 4 years.
3. The Adjusted Crops Loss includes an allowance for a reduction of yield of 60 percent and an expected flood incidence of one in 4 years; values have been rounded to the nearest dollar.

Table S7 - Monthly Schedule of Farm Activities, Production Costs, Revenue and Crop Loss Values: WINTER WHEAT (1976 dollars per acre)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Variable Production Costs													
Land Rent									20				20
Land Preparation									15				15
Seed									6	6			12
Fertilizer									7	7			14
Planting									4	4			8
Weed/Pest Control				5									5
Drainage													
Irrigation													
Cultivation													
Harvest							6	12					18
Monthly Increment				5			6	12	52	17			
Accumulated Cost	69	69	69	74	74	74	80	92	52	69	69	69	
Total Variable Production Costs	92	92	92	92	92	92	92	92	92	92	92	92	92
Expended	69	69	69	74	74	74	80	92	52	69	69	69	
Unexpended	23	23	23	18	18	18	12	0	40	23	23	23	
Gross Revenue	98	98	98	98	98	98	98	98	98	98	98	98	98
Crop Loss 1/	75	75	75	80	80	80	86	98	58	75	75	75	

1/ Gross revenue minus unexpended variable production costs.

Table S8 - Monthly Schedule of Farm Activities, Production Costs, Revenue and Crop Loss Values: OATS (1976 dollars per acre)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Variable Production Costs													
Land Rent				20									20
Land Preparation				10									10
Seed				5	5								10
Fertilizer					14								14
Planting				4	4								8
Weed/Pest Control						5							5
Drainage													
Irrigation													
Cultivation													
Harvest								18					18
Monthly Increment				39	23	5		18					
Accumulated Cost				39	62	67	67	85					
Total Variable Production Costs				85	85	85	85	85					85
Expended				39	62	67	67	85					
Unexpended				46	23	18	18	0					
Gross Revenue				78	78	78	78	78					78
Crop Loss 1/				32	55	60	60	78					

1/ Gross revenue minus unexpended variable production costs.

Table S9 - Monthly Schedule of Farm Activities, Production Costs, Revenue and Crop Loss Values: BUCKWHEAT (1976 dollars per acre)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Variable Production Costs													
Land Rent						20							20
Land Preparation						10							10
Seed							7						7
Fertilizer							7						7
Planting													
Weed/Pest Control						5							5
Drainage													
Irrigation													
Cultivation													
Harvest										15			15
Monthly Increment						35	14			15			
Accumulated Cost						35	49	49	49	64			
Total Variable Production Costs						64	64	64	64	64			64
Expended						35	49	49	49	64			
Unexpended						29	15	15	15	0			
Gross Revenue						100	100	100	100	100			100
Crop Loss 1/						71	85	85	85	100			

1/ Gross revenue minus unexpended variable production costs.

Average monthly nongrowing season loss value for each major crop grown on the flood plain is summarized in Table S10.

Table S10 - Average Monthly Nongrowing Season Loss Values 2/
(1976 Normalized Prices)

Crop	Loss Value
	$
Corn, silage	0.0
Corn, grain	0.0
Wheat, winter	75.83
Oats	5.33
Buckwheat	0.00
Hay, mixed	16.50
Miscellaneous crops	190.00 1/

1/ As this is a category containing several crops, as opposed to being a homogeneous crop type, no schedule is presented for it among Tables S4-S9. This estimate was developed using the same methodology as used in estimating the loss value for the six identified crops.

2/ Nongrowing season consists of the period November through April.

S2.2 Existing Agricultural Damages and Benefits

Agricultural inundation damages presented in this report are based on the concept of agricultural loss which is defined to be gross revenue per acre minus unexpended variable production costs required to produce the crop. The monthly schedules of gross revenue, variable production costs, and the resulting potential agricultural loss (income foregone) per crop were integrated to produce a schedule for the "nongrowing season," 1 November through 30 April. As there have been only four floods where the stream crest was more than .3 foot above the zero damage level in the summer, or "growing season," in the past 56 years (during which period there were a total of 81 floods), damages and benefits have been calculated only for the nongrowing season. Though this may underestimate agricultural damages and benefits, it is a more conservative approach than the alternative which involves weighting economic losses according to the seasonal frequency of flood probabilities. Principal problems of the latter approach lay in the inability to accurately project changes in the frequency of summer or "growing season" floods after completion of the project and the difficulty in measuring the effect that frequency has upon the magnitude of improved hydraulic conditions, damages, and benefits.

a. Average Annual Agricultural Damages, Existing Conditions. A weighted average agricultural loss value per acre of sown cropland was calculated for the nongrowing season with the weights being the percentage each crop is of total sown cropland in the reach. The nongrowing season average loss value per acre was developed on the basis of gross revenue, variable production cost data, and monthly farm activity schedules for each crop.

A stage-area curve for agricultural land, which was originally defined as sown cropland plus pasture and idle agricultural land, was developed for each reach and is presented as Plates S1 to S20. These relationships were developed from the analysis of agriculture on the flood plain and by planimetering affected areas on USGS topographic maps for the Standard Project Flood, the Intermediate Regional Flood, the 1960 flood, and the bankfull stage.

Approximate agricultural damages for existing conditions by reach were calculated by multiplying the affected agricultural area (cropland plus pasture and idle agricultural land) at each stage, by the weighted average loss value per acre of sown cropland in the reach. The resulting products were then computer processed using the March 1979 version of Expected Average Annual Damage Program from the Hydrologic Engineering Center (HEC) to estimate "approximate" damage-frequency relationships for each reach. For purposes of computing damages, the Standard Project Flood was assigned an occurrence frequency of once in 1,000 years.

The agricultural damages produced by this process are termed "approximate" because they overestimate the "correct" agricultural damage figures. The reason for this is that while the agricultural loss value per acre was based only on acreage of sown crops, the stage-area relationship includes the area for total agricultural land, sown cropland plus pasture, and idle agricultural land. To adjust for this, the approximate agricultural damages for

each reach were reduced by the proportion of sown cropland to total agricultural land. The resulting average annual inundation damages for each reach are presented in Table S11, Existing Average Agricultural Damages by Reach (1976 prices).

To illustrate the methodology described above, the calculation of average annual agricultural damages for Reach T-5 is summarized below. The following data are required to calculate damages; an agricultural stage-area curve (Plate S3); acreage of existing sown cropland and the percent distribution of the same (columns 1 and 2 of Table S12, respectively); the nongrowing season loss value per acre for each crop sown (column 3 of Table S12); and the nongrowing, season-weighted, average agricultural loss value per acre of sown cropland (column 4 of Table S12). The last is the product of the percent a crop is of all sown cropland in the reach and the nongrowing season loss value per acre for the crop in question (columns 2 and 3 of Table S12). Since the growing season loss has been ignored as a source of agricultural damages, the sum of the last column in Table S12 (column 4, the nongrowing season weighted loss value per acre of sown cropland) is the average loss value per acre of sown cropland in the reach. The weighted agricultural loss per cropped acre in Reach T-5 is $15.67.

Table S13 presents stages and acreage in Reach T-5. At a given stage (column 1) the agricultural area (column 3) from the stage-area curve (Plate S3) is multiplied by the average agricultural loss value per acre of sown cropland in the reach ($15.67 per acre, column 2), to produce an estimate of the agricultural loss to be incurred by all agriculture in the reach when future floods reach the indicated stage. In Reach T-5, the Standard Project Flood stage, that corresponding to a flood which has a frequency of occurring once in 1,000 years, is 587.8 feet. Thus a Standard Project Flood will produce an estimated loss of $16,300 ($15.67 per acre times 1,038 acres) in Reach T-5. The integration of all potential damages from the zero damage stage to the Standard Project Flood Stage with the frequency of occurrence produces an estimate of average annual damages. This is subsequently adjusted downward by the proportion that sown cropland is of all agricultural land in the reach, 85.6 percent, to produce the final estimate of average annual agricultural damages in Reach T-5, $4,920 per year in 1976 prices (Table S13).

b. Average Annual Agricultural Damages, Improved Conditions. Residual average damages have been computed for the Batavia Reservoir Compound Modified (BRCM) using improved stage-frequency values. Computations are based upon the March 1979 version of the Expected Average Damage Program of the Hydrologic Engineering Center (HEC). Table S14 presents the residual average annual agricultural inundation damages for each reach in 1976 prices based upon 1978 agricultural land use.

c. Average Annual Agricultural Benefits, Existing Conditions. Existing average annual agricultural benefits (agricultural inundation reduction benefits) are summarized in Table S15. The BRCM is estimated to reduce average annual losses by $64,400.

Table S11 - Existing Average Annual Agricultural Damages by Reach (1976 prices)

Reach	Damages
	$
T-1	0
T-2	0
T-3	1,410
T-4	20
T-5	4,920
T-6	18,610
T-7	3,640
T-8	4,600
T-9	11,610
T-10	0
Subtotal	44,810
RB-1	350
RB-2	1,180
RB-3	22,510
RB-4	10,630
Subtotal	34,670
M-1	0
M-2	170
M-3	320
M-4	240
M-5	4,030
M-6	6,220
Subtotal	10,980
T-11	370
T-12	1,520
Subtotal	1,890
B-1	0
B-2	0
B-3	0
B-4	0
B-5	0
Subtotal	0
T-13	1,630
A1-3 1/	-
Grand Total	93,980

1/ No damages have been calculated for these reaches as they are above the upstream limits of the proposed project site.

Table S12 - Average Agricultural Loss Calculations - Reach T-5

Crop	(1) Existing Sown Cropland	(2) Existing Sown Cropland	(3) Nongrowing Season Loss Value[1/]	(4) Nongrowing Season Weighted Loss Value Per Acre of Sown Cropland (Column 2 X 3)
	acres	percent	$	(dollars per acre)
Corn - silage	620	52.1	0.0	0.0
Corn - grain	30	2.5	0.0	0.0
Wheat (winter)	20	1.7	75.83	1.29
Oats	60	5.0	5.33	0.27
Buckwheat	180	15.1	0.0	0.0
Hay, mixed	210	17.6	16.50	2.90
Miscellaneous Crops	70	5.9	190.00	11.21
All Sown Crops	1,190	99.9		15.67

1/ Dollars per acre from Table S10.

Table S13 - Calculation of Average Annual Agricultural Damages in Reach T-5

(1) Stage	(2) Average Loss Value Per Acre of Sown Cropland	(3) Agricultural Area (acres)	(4) Potential Agricultural Loss
	$		$
587.8 1/	15.67	1,038	16,300
587.4	15.67	975	15,300
587.0	15.67	900	14,100
586.4	15.67	800	12,500
586.0	15.67	725	11,400
585.4	15.67	600	9,400
585.0	15.67	500	7,800
584.4	15.67	350	5,500
584.0	15.67	250	3,900
583.4	15.67	100	1,600
583.0	15.67	0	0

1/ The Standard Project Flood Stage for the reach.
Approximate annual agricultural damages in the reach = $5,740, however, the adjusted value is equal to the approximate average annual agricultural damages in the reach ($5,740) times the percentage that sown cropland is to total agricultural land in the reach (i.e., about 85.6 percent). This results in a revised estimate of $4,920 for Reach T-5.

Table S14 - Average Annual Agricultural Residual Damages by Reach (1976 prices and 1978 crop patterns)

Reach	Plan 3
T-1	0
T-2	0
T-3	110
T-4	0
T-5	1,070
T-6	7,100
T-7	830
T-8	1,290
T-9	2,830
T-10	0
Subtotal	13,230
RB-1	120
RB-2	330
RB-3	7,340
RB-4	2,880
Subtotal	10,670
M-1	0
M-2	70
M-3	80
M-4	70
M-5	1,490
M-6	2,120
Subtotal	3,830
T-11	60
T-12	120
Subtotal	260
B-1	0
B-2	0
B-3	0
B-4	0
B-5	0
Subtotal	0
T-13	1,620 1/
A1-3 2/	-
Grand Total	29,610

1/ Residual damages are slightly greater due to storage of floodwater.

2/ No damages have been calculated for these reaches as they are located upstream of the project site.

Table S15 - Summary of Existing Average Annual Agricultural Damages and Benefits (1976 prices and 1978 Land Use Patterns)

Reaches	Existing Damages	BRCM Residual Damages	BRCM Benefits
	$	$	$
T1-10	44,800	13,200	31,600
RB1-4	34,700	10,700	24,000
M1-6	11,000	3,800	7,200
T11&12	1,900	300	1,600
B1-5	0	0	0
T-13	1,600	1,600	0
A1-3 1/	-	-	-
Total 2/	94,000	29,600	64,400

1/ No damages have been calculated for these reaches as they are located upstream of the project site.

2/ Totals may not add due to rounding.

S2.3 Future Agricultural Benefits

a. Agricultural Intensification. The recommended plan, BRCM, will have a significant impact upon agriculture on the flood plain. It is projected to: (1) eliminate almost all summer floods, except the most rare and extremely severe summer floods; and (2) eliminate most late autumn (November) and spring (April) floods.

Besides reducing the level of agriculture losses on the flood plain, the project will significantly alter the character of future agricultural operations. This net change is defined as the agricultural intensification benefit.

Agricultural intensification will result from two factors: (1) an extension of the effective growing season, which will enable the farmers to plant crops earlier in the spring, due to elimination of most April floods; and (2) a change in farmers' behavior toward more intensive agriculture. These factors will combine to increase the productivity of farmers operating on the flood plain, increasing their yields up to the levels permitted by the productivity of major soils; given good management practices and elimination of the flood hazard.

Agricultural intensification benefits attributable to the project have been acknowledged by three independent sources; the consultant's report of agriculture on the flood plain, local Soil Conservation Service officials in Erie and Genesee Counties, and Cooperative Extension Agent, Erie County.

(1) Increase in Gross Profitability - It is projected that farm operators will intensify their operations by some combination of two methods: planting crops at a more appropriate earlier date in the spring, and bringing idle agricultural acreage into a higher economic use. The Soil Conservation Service and Cooperative Extension Agents in Erie and Genesee Counties have indicated that they will disseminate information to affected farmers regarding the advantages and methods for intensifying their operations.

It has been assumed that during a 10-year period after completion of the project, (P_{10} or 1995), farmers on the flood plain will intensify their agricultural operations. Based on information from secondary sources, it is projected that the elimination of the most frequent type of spring flooding accompanied by the extension of the effective growing season will increase the yields of the principal crops, as presented in Table S16. With the projected increase, flood plain farmers will raise their productivity to a level permitted by the productivity of major soils; given good management practices and elimination of the flood hazard.

Table S16 - Future Yields After Agricultural Intensification

Crop	1978 Yield (units/acre)	1995 Yield (units/acre)	Percent Change 1/
			%
Corn, silage	11.4 tons	17.1 tons	50
Corn, grain	65.2 bushels	95.7 bushels	47
Oats	47.1 bushels	80.3 bushels	70
Mixed Hay	2.5 tons	4.2 tons	68
Winter Wheat	31.0 bushels	48.2 bushels	55

1/ Weighted average increase in crop yields based upon distribution of major soil associations and elimination of early spring floods.

No increase in the yields of miscellaneous crops has been projected because of the very high value and the heterogeneous mix of crops contained in this category. Eliminating this group of crops produces a conservative estimate of the future increases to be obtained through intensified farm operation.

Table S17 summarizes the net increase in gross profits per acre for those crops which have been projected to benefit from intensified farm operation.

Table S17 - Change in Gross Profits Per Acre for Selected Crops (1976 dollars)

Crop	Existing Conditions (1978)	Intensified Operations (1995)	Change in Gross Profits
	$	$	$
Corn, silage	90	198	108
Corn, grain	43	120	77
Oats	-7	48	41
Hay, Mixed	19	102	83
Winter Wheat	6	60	54

A small portion of the increased profitability of agriculture on the flood plain is the result of the projection that over a 10-year period, from 1985 (Project Year One) to 1995, 50 percent of the idle agricultural land for most reaches in the flood plain will be brought into agricultural production.

Coordination of this potential change in land use patterns with local agricultural officials concluded that the distribution of this incremental acreage would be approximately equal to the 1978 distribution of sown cropland, excluding miscellaneous crops. The latter were excluded because of their high value per acre which could give them excessive weight in the allocation and because it is inappropriate in a dairy farming region to project a specific rate of conversion of idle land into production of very specialized cash crops such as strawberries, cabbage, sod, flowers, etc. Few dairy farmers could be expected to have the knowledge, experience, and equipment needed to convert their idle land to these crops.

The conversion of vacant land to sown cropland in the proportion that the latter were planted on the flood plain in 1978 is but one of any number of allocation scenarios that could have been used. However, it has the support of local Soil Conservation officials. Conversion of idle land entirely into corn for silage, for example, would generate higher intensification benefits, but no defensible argument for such a drastic change is readily available. Table S18 presents the annual increase in profitability, in 1976 prices, that is projected to accrue to agriculture on the flood plain by 1995 as a result of intensification of agricultural operations.

Table S18 - Annual Increase in the Gross Profitability 1/

Crop	Change in Gross Profits/Acre ($/acre)	Projected 1995 Sown Cropland (acres)	Increase in Gross Profits 2/ ($)
Corn, silage	108	6,430	694,440
Corn, grain	77	440	33,880
Oats	41	1,880	77,080
Hay, Mixed	83	3,170	263,110
Winter Wheat	54	1,615	87,210
Subtotal			1,155,720

1/ Increase in yields and shift of vacant agricultural land into cropland.
2/ Ten-year straight-line growth, 100-year project life, project interest rate of 7.375 percent ($1,155,720 X .7410 = $856,400).

When the estimated $1,155,720 increase in gross profits per year is attained in 1995 and converted to its equivalent annual value, agricultural intensification generates an increase in gross agricultural profits of $856,400 per year. This projection is based upon use of a straight-line growth function for the 1985-1995 period and the 7.375 percent project interest rate.

(2) Increase in Residual Damages - Increased profitability of agriculture on the flood plain will be partly offset by an increase in residual damages resulting from the presence of higher value crops after completion of the project. Future residual damages have been calculated by using a weighted average agricultural loss value per acre of sown cropland in each reach under the intensified conditions projected to exist in 1995, and the improved condition stage-frequency curves for each reach. The net increase in future residuals for the BRCM assuming a scenario of intensified agricultural operations, are estimated to be $14,200.

Table S19 - Change in Agricultural Intensification Residual Damages

	BRCM			
	Intensification	Non-Intensified	Increase in Residuals	
Reaches	Residuals	Residuals	1976 Prices	1980 Prices 2/
	$	$	$	$
T1-10	25,660	13,230	12,430	11,980
RB1-4	10,690	10,670	20	10
M1-6	3,830	3,830	0	0
T11-12	310	260	50	40
B1-5	0	0	0	0
T-13	3,320	1,620	1,700	1,690
A1-3 1/	-	-	-	-
Total	43,810	29,610	14,200	13,720

1/ No damages were calculated for these reaches as they are located upstream of the project sites.

2/ Normalized prices for sown cropland have decreased between 1976 and 1980

(3) Net Intensification Benefits - Net agricultural intensification benefits are estimated by converting the future increase in residual damages to its discounted equivalent annual value; this is equal to $10,170 expressed at 1980 price levels (e.g., $13,720 X .7410 = $10,170). This subtotal is then deducted from the net annual increase in gross profitability. The BRCM plan has been credited with $824,390 of future net intensification benefits. A summary of these calculations is included in Table S20.

Table S20 - Average Annual Agricultural Intensification Benefits - BRCM (1980 Prices)

Reach	1976 Prices Net Increase in Gross Profits	1980 Prices 1/ Net Increase in Gross Profits	Equivalent Annual Increase in Gross Profits	Average Annual Increase in Residual Damages	Equivalent Agricultural Intensification Benefits
T1-10	572,850	555,100	411,330	8,880	402,450
RB1-4	72,435	71,960	53,320	10	53,310
M1-6	313,890	305,550	226,410	0	226,410
T11-12	38,275	36,970	27,390	30	27,360
B1-5	0	0	0	0	0
T-13	158,270	156,690	116,110	1,250	114,860
A1-3	2/	2/	2/	2/	2/
Total	1,155,720	1,126,270	834,560	10,170	824,390

1/ Total annualized increase in profitability (1,155,720 reference Table S18) updated to 1980 price levels.

2/ These reaches are located upstream of the project and no intensification benefits have been

(4) Overview and Conclusions on Future Agricultural Intensification - The magnitude of the estimated agricultural intensification benefits is based upon two assumptions: (1) all summer (May through October) floods will be eliminated by the project; and (2) late spring (April) and late autumn (November) floods will be eliminated or substantially reduced in frequency. As a result of these effects, yields are projected to increase because: (1) crops will be planted and harvested in accordance with a schedule to maximize yields; and (2) farmers will intensify their operations in response to the decreased annual flood hazard.

The first premise is easily met. Hydraulic investigations of the BRCM Plan indicated that during the summer months, this plan would provide protection substantially beyond the IRF level. The second premise remains, and its validity is crucial. Since the need to plant crops at an optimal date in the spring is much more critical than the timing of the harvest in autumn, which only affects the corn crop, the reliability of the estimates of agricultural intensification benefits depends upon the degree to which April floods will be reduced in frequency.

The argument that the project will eliminate most April floods has been developed for the major agricultural reaches, those with more than 800 acres of agricultural land. This includes reaches: T-5 through T-9; RB-3; M-3, M-5 and M-6, and T-13. These 10 reaches included about 78 percent of the agricultural land on the flood plain.

The data used to support the methodology includes the stage-frequency curves for the above-mentioned reaches (Plates S3-S7, S10, S14, S16, S17, and S20), and the historical data of flood levels at the Alabama Gage on Tonawanda Creek. This gage is located on the creek at Hopkins Road; it is the boundary between reaches T-10 and T-11. Observations at this gage site are based on a 56-year period from 1922 through 1977.

In Reach T-5, the return period for a minimal flood, one with a stage just above zero damage (583.0 ft.), increases under existing conditions from once in 10 months to once in 4 years under improved conditions. Correspondingly, there is a 2.0-foot reduction in the stage of the minimal flood for the BRCM from 585.0 feet for existing conditions to 583.0 feet. Table S21 presents the reduction in flood stage for the most important agricultural reaches.

It is possible to estimate the probable impact the BRCM would have on the frequency of April floods by comparing the frequency with which April floods would have occurred in the 1922-1977 period, if the project had been in place at that time, with the frequency April floods did occur in the same period. The former depends, of course, on the reduction in the stage that one selects. If, for example, it is assumed that the stage will be reduced by the average reduction in reaches T-5 through T-9 (2.4 feet in Table S21), it will be seen that only two floods (1940 and 1941) would have occurred if the project had been in place (Tables S21 and S22). In this situation, the relative frequency of an April flood with project conditions would be 3.6 percent as compared to the recorded frequency under existing conditions, 46.4 percent (Table S23). The former could be expected to occur once every 27.3 years while the latter could be expected to occur once every 2.2 years.

Table S21 - Impact of BRCM on Historical Flood Frequencies

Reach Number	Zero Damage Stage	Exceedance Frequency Existing Conditions	Exceedance Frequency Improved Conditions	Existing Stage at Improved Exceedance Frequency	Stage Reduction with BRCM
T-5	583.0	10 Months	4 Years	585.0	2.0
T-6	587.0	6 Months	18 Months	589.9	2.9
T-7	593.0	8 Months	2.5 Years	595.4	2.4
T-8	597.0	6 Months	1.75 Years	599.6	2.6
T-9	601.0	6 Months	2.22 Years	602.9	1.9
Mean Reduction					2.4
RB-3	584.0	9 Months	2.70 Years	585.9	1.9
M-3	590.3	5.8 Years	16.66 Years	591.1	0.8
M-5	598.0	1.5 Years	4.35 Years	600.1	2.1
M-6	603.5	3.3 Years	9.10 Years	604.5	1.0
Mean Reduction					1.3
Grand Mean					1.9
Mode					2.0

Table S22 - April Floods of Record at the Alabama Gage, Tonawanda Creek: 1922-1977

Year	Gage Height of Crest (Feet)	Crest Height Above Bank-Full Stage 1/ (Feet)
1924	11.1	.1
1929	11.6	.6
1937	11.1	.1
1940	14.5	3.5
1941	14.0	3.0
1942	12.0	1.0
1943	11.1	.1
1944	12.3	1.3
1947	12.0	1.0
1950	12.1	1.1
1951	11.7	.7
1954	11.8	.8
1956	12.2	1.2
1956	11.5	.5
1956	11.6	.6
1957	12.1	1.1
1958	12.3	1.3
1959	14.1	2.1
1961	12.9	1.9
1965	11.8	.8
1970	12.1	1.1
1973	11.3	.3
1974	11.7	.7
1974	11.5	.5
1976	11.5	.5
1977	12.5	1.5

1/ A flood event is defined as any stage above a bank-full gage height of 11.0 feet.

Source: Flood Plain Information, Tonawanda Creek And Its Affected Tributaries, Buffalo District, Corps of Engineers, August-1967 (reprinted June 1971) pp 43-47; and Water Resource Data for New York, USGS for years 1966-1977.

Table S23 - Impact of Flood Damage Management on Period of Record

Reduction in Stage (feet)	Number of Floods	Relative Frequency 1/	Frequency (Years/Flood)
0.0	26	.464	2.2
0.8	14	.250	4.0
1.3	6	.107	9.3
1.9	3	.054	18.5
2.4	2	.036	27.3

1/ Probability of a flood occurring during the period of record (56 years) assuming the extent of stage reduction from Column 1.

Without historical data on the number of floods and corresponding stages for each reach, it is not possible to definitely estimate the effect the project would have in reducing the frequency of April floods throughout the basin. Also, it is not possible to definitively estimate the basin-wide reduction in April floods that would occur on the flood plain after implementation of the project. However, considering that in nine of the ten major agricultural reaches the mean and the modal values of the reduction in the minimal flood stage are within one-tenth of a foot (Table S21), it is reasonable to conclude that the vast majority of all April floods, 23 out of 26, would have been eliminated had the project been in place at the time. This would have reduced the occurrence of April floods to once in 18.5 years as opposed to the historical occurrence of once in 2.2 years (Table S23). While there can be no assurance that a future 56-year period would replicate the experience of the 1922-1977 period, the probability is very high that future conditions will closely resemble that of the past.

The estimated reduction in the average frequency of an April flood from once every 2.2 years to once every 18.5 years represents a very sharp reduction in the perceived risk of farmers operating on the flood plain. Thus the threat of an April flood, with the associated problem of delaying planting beyond the optimal date, would no longer preclude more intensive operation. Benefits from more intensified farm operations, i.e., those designed to bring yields up to the level of farmers located in the basin but situated off the flood plain, have been credited to the proposed project.

b. Projected Growth of Future Agricultural Benefits. The value of agricultural output on the flood plain has been rising, and it is projected to continue to rise into the future. Basically this represents the regional component of a national secular trend of rising agricultural productivity and output in the future acknowledged by the U.S. Water Resources Council (1972 OBERS Projections, Regional Economic Activity in the U.S., May 1975).

The growth of agricultural benefits was determined to be equal to the mean percent increase of the value of crop production for the Water Resources Council Subareas 412 (Eastern Lake Erie) and 413 (Southwestern Lake Ontario) combined, and Region 4 (Great Lakes), as projected in OBERS Projections Regional Economic Activity in the U.S., Series E Population, Vol. 1, U. S. Water Resources Council, Washington, DC, 1972, p. 84. The reason for selecting this rate of growth is that while it is expected the value of crop production on the flood plain will not grow as rapidly as that of the entire Great Lakes Region, which is primarily a dairy farming region, it will grow faster than the rate of growth projected for the two subareas, which are biased by the predominance of vineyards along Lake Erie and orchards along Lake Ontario.

As previously stated 1978 conditions of development in the agricultural sector are assumed to approximate 1980 conditions. The value of agricultural benefits in the flood plain has been projected to grow to $64,730 by project base year (1985), and will continue to grow to $74,250 in project year 50 (2035).

The benefits contributed by this category of long-term projected growth within the agriculture sector are summarized in Table S24 and are relatively minor. The BRCM has been credited with $3,820 in average annual benefits.

Table S24 - Discounted Future Agricultural Benefits
(1980 prices) - BRCM

Year	Benefits 1/	Interval	Net Increase 2/	Average Annual Equiv. Factor	Present Worth of $1 Per Period	Present Worth Factor	Amortization Factor	Discounted Average Annual Benefits
1985	64,730							
		1985-1995	3,500	.7410	-	-	-	2,590
1995	68,230							
		1995-2005	2,350	.7408	13.53689	.49087	.07381	850
2005	70,580							
		2005-2015	1,210	.7404	13.51361	.24096	.07381	220
2015	71,790							
		2015-2025	1,220	.7395	13.46621	.11828	.07381	110
2025	73,010							
		2025-2035	1,240	.7376	13.36963	.05806	.07381	50
2035	74,250							
Total								3,820

1/ Assumes straight line growth between points

2/ Net increase in the value of agricultural benefits attributed to national productivity gains

3/ Interest rate of 7-3/8 percent and 100-year project.

S2.4 Summary of Agricultural Benefits

Table S25 summarizes estimated average annual agricultural benefits estimated. Construction of the BRCM would result in agricultural benefits of $892,810.

Table S25 - Summary of Average Annual Agricultural Benefits (1980 prices)

	BRCM
	$
Existing Conditions	64,730
Inundation Reduction Benefits	64,730
Future Benefits	828,080
Intensification Benefits	824,390
Projected Growth of Future Agricultural Benefits	3,820
Total Agricultural Benefits	828,210

S3. URBAN

S3.1 Conditions of Development

Damages and benefits have been developed for two levels of development: 1975 and Project Year One (1985) conditions. The 1975 conditions are based on detailed damage surveys conducted in November and December of that year. Damages and benefits for Project Year One consist of 1975 damages and benefits adjusted for short-term future development anticipated to occur within the flood plain by 1985. All damages and benefits are shown at 1975 prices and also at June 1980 price levels.

a. 1975 Development Conditions. A benefit-cost summary for existing conditions is based upon 1975 conditions of development. Existing conditions benefits consist of inundation reduction benefits. This display of project benefits and costs is required to measure the extent of project feasibility as a result of current development on the flood plain. Usually, if a project is justified based upon existing development, analysis of future development and benefits may be accomplished in an abbreviated manner.

(1) Inundation Reduction Damages and Benefits - Average Annual Damages, Existing Conditions - Inundation damages are flood damages and losses to existing structures and their contents. Flood profiles for the Intermediate Regional Flood and the Standard Project Flood were used as a basis for determining flood damages on the flood plain. A stage-damage relationship by reach was developed for each category of activity: residential, commercial and industrial, and public and other. These data were processed using the Expected Average Annual Damage Program to produce the estimates of average annual damages for existing conditions. These damages assume a 1,000-year return period for the SPF and 1975 development conditions. Estimated average annual damages under existing (1975 development) conditions by reach are presented in December 1975 prices in Table S26 and in June 1980 prices in Table S27.

Average Annual Damages, Improved Conditions - Residual average annual damages have been computed for the recommended plan of improvement. Stage-frequency curves under improved conditions were used in conjunction with the appropriate stage-damage relationships to determine the damage-frequency relationship for each reach. These data were also processed using the Expected Average Annual Damage Program. These damage estimates assume a 1,000-year return period for the SPF, 1975 development conditions and prices. Residual average annual damages are summarized in December 1975 prices in Table S28 and June 1980 prices in Table S29.

Average Annual Inundation Reduction Benefits - The inundation reduction benefit is the value of reduced flood damages under 1975 development conditions. It is calculated by subtracting the estimated residual average annual damages under improved conditions from the average annual damages under existing conditions. Average annual inundation benefits are summarized in December 1975 prices in Table S28 and June 1980 prices in Table S29.

Table S26 - Estimated Average Annual Damages, Existing Conditions by Reach (December 1975 Development Conditions and Prices)

Reach	Residential	Commercial and Industrial	Public and Other	Agricultural 1/	Total
T-1	30,210	60	3,500	0	33,770
T-2	12,480	10	8,940	0	21,430
T-3	8,750	2,380	11,800	1,410	24,340
T-4	380	0	1,080	20	1,480
T-5	98,360	10	13,910	4,920	117,200
T-6	200,740	0	11,400	18,610	230,750
T-7	60,620	0	15,680	3,640	79,940
T-8	96,860	50	14,110	4,600	115,620
T-9	63,720	0	14,880	11,610	90,210
T-10	2,920	0	1,220	0	4,140
RB-1	24,410	0	660	350	25,420
RB-2	83,410	1,380	11,210	1,180	97,180
RB-3	116,930	0	57,020	22,510	196,460
RB-4	53,660	670	4,970	10,630	69,930
M-1	580	0	3,280	0	3,860
M-2	800	0	0	170	970
M-3	2,490	0	210	320	3,020
M-4	3,180	0	190	240	3,610
M-5	18,940	0	770	4,030	23,740
M-6	17,120	0	1,740	6,220	25,080
T-11	7,170	0	9,340	370	16,880
T-12	15,020	2,670	18,710	1,520	37,920
B-1	26,360	6,250	23,500	0	56,110
B-2	2,120	0	4,450	0	6,570
B-3	53,920	57,000	10,870	0	121,790
B-4	19,170	380	1,410	0	20,960
B-5	540	18,590	2,180	0	21,310
T-13	22,220	0	7,690	1,630	31,540
A-1	15,150	2/	2/	3/	15,150
A-2	14,130	2/	2/	3/	14,130
A-3	6,520	2/	2/	3/	6,520
Total	1,078,880	89,450	254,720	93,980	1,517,030

1/ For the agricultural sector, land use patterns are based on 1978 conditions and 1976 normalized prices.
2/ Included in residential.
3/ Not calculated on those reaches as they are located upstream of the project sites.

Table S27 - Estimated Average Annual Damages, Existing Conditions by Reach, June 1980 Prices and December 1975 Conditions of Development

Reach	Residential	Commercial and Industrial	Public and Other	Agricultural 1/	Total
T-1	43,810	90	5,040	0	48,940
T-2	18,100	20	16,830	0	34,950
T-3	12,690	3,450	16,990	1,400	34,530
T-4	550	0	1,560	20	2,130
T-5	142,620	20	20,030	4,530	167,200
T-6	291,070	0	16,420	17,870	325,360
T-7	87,900	0	22,580	3,680	114,160
T-8	140,450	0	20,320	4,550	165,390
T-9	92,390	0	21,430	10,910	124,730
T-10	4,230	0	1,760	0	5,990
RB-1	35,400	0	950	350	36,700
RB-2	120,950	2,000	16,140	1,170	140,260
RB-3	169,550	0	82,110	22,290	273,950
RB-4	77,810	970	7,160	10,630	96,570
M-1	840	0	6,180	0	7,020
M-2	1,160	0	0	170	1,330
M-3	4,740	0	300	310	5,350
M-4	4,610	0	270	230	5,110
M-5	27,460	0	1,110	4,030	32,600
M-6	24,820	0	2,510	5,850	33,180
T-11	10,400	0	13,450	360	24,210
T-12	21,780	3,870	26,940	1,500	54,090
B-1	38,220	9,060	33,840	0	81,120
B-2	3,070	0	6,410	0	9,480
B-3	78,180	82,650	15,650	0	176,480
B-4	27,800	550	2,030	0	30,380
B-5	780	26,960	3,140	0	30,880
T-13	32,220	0	11,070	1,610	44,900
A-1	21,970	2/	2/	3/	21,970
A-2	20,490	2/	2/	3/	20,490
A-3	9,450	2/	2/	3/	9,450
Total	1,565,510	129,710	372,220	91,460	2,158,900

1/ For the agricultural sector, development conditions are at 1978 levels.
2/ Included in residential.
3/ Not calculated on those reaches as they are located upstream of the project site.

Table S28 - Estimated Existing Average Annual Damages and Benefits
(December 1975 Development Conditions and Prices)

Reach Number	Reach Name	Existing Average Annual Damages	BRCM Residual Average Annual Damages	BRCM Existing Average Annual Benefits
		$	$	$
T1-T10	Lower Tonawanda Creek			
	Residential	575,040	165,890	409,150
	Commercial and Industrial	2,510	310	2,200
	Public and Other	96,520	20,340	76,180
	Agriculture 1/	44,810	13,230	31,580
	Subtotal	718,880	199,770	519,110
RB1-RB4	Ransom and Black Creek			
	Residential	278,410	83,940	194,470
	Commercial and Industrial	2,050	640	1,410
	Public and Other	73,860	25,470	48,390
	Agriculture 1/	34,670	10,670	24,000
	Subtotal	388,990	120,720	268,270
M1-M6	Mud Creek			
	Residential	43,110	13,050	30,060
	Commercial and Industrial	0	0	0
	Public and Other	6,190	520	5,670
	Agriculture 1/	10,980	3,830	7,150
	Subtotal	60,280	17,400	42,880
	Total Huron Plain	1,168,150	337,890	830,260
T11-T12	Tonawanda Creek: Meadville Road to City of Batavia			
	Residential	22,190	1,560	20,630
	Commercial and Industrial	2,670	260	2,410
	Public and Other	28,050	830	27,220
	Agriculture 1/	1,890	260	1,630
	Subtotal	54,800	2,910	51,890
B1-B5	City of Batavia			
	Residential	102,110	6,280	95,830
	Commercial and Industrial	82,220	150	82,070
	Public and Other	42,410	840	41,570
	Agriculture 1/	0	0	0
	Subtotal	226,740	7,270	219,470

Table S28 - Estimated Existing Average Annual Damages and Benefits (December 1975 Development Conditions and Prices) (Cont'd)

Reach Number	Reach Name	Existing Average Annual Damages	BRCM Residual Average Annual Damages	BRCM Existing Average Annual Benefits
		$	$	$
T-13	Batavia to Alexander			
	Residential	22,220	0	22,220
	Commercial and Industrial	0	0	0
	Public and Other	7,690	0	7,690
	Agriculture 1/	1,630	1,620	10
	Subtotal	31,540	1,620	29,920
A-1	Alexander			
	Residential	15,150	15,150	0
	Commercial and Industrial	2/	2/	2/
	Public and Other	2/	2/	2/
	Agriculture 1/	3/	3/	3/
	Subtotal	15,150	15,150	0
A2-A3	Attica			
	Residential	20,650	20,650	0
	Commercial and Industrial	2/	2/	2/
	Public and Other	2/	2/	2/
	Agriculture 1/	3/	3/	3/
	Subtotal	20,650	20,650	0
	Total Erie Plain	348,880	47,600	301,280
	Total Tonawanda Creek Watershed			
	Residential	1,078,880	306,520	772,360
	Commercial and Industrial	89,450	1,360	88,090
	Public and Other	254,720	48,000	206,720
	Agriculture 1/	93,980	29,610	64,370
	Grand Total	1,517,030	385,490	1,131,540

1/ Agriculture development is for 1978 and prices are for 1976.
2/ Included in residential.
3/ Not calculated as these reaches are upstream of the project.

Table S29 - Estimated Existing Average Annual Damages and Benefits (December 1975 Development Conditions and June 1980 Prices)

Reach Number	Reach Name	Existing Average Annual Damages	BRCM Residual Average Annual Damages	BRCM Existing Average Annual Benefits
		$	$	$
T1-T10	Lower Tonawanda Creek			
	Residential	833,800	240,540	593,300
	Commercial and Industrial	3,640	450	3,190
	Public and Other	139,000	29,290	109,700
	Agriculture 1/	42,950	12,680	30,300
	Subtotal	1,019,400	282,960	736,490
RB 1-4	Ransom and Black Creek			
	Residential	403,700	121,710	281,980
	Commercial and Industrial	3,000	930	2,040
	Public and Other	106,360	36,680	69,680
	Agriculture 1/	34,430	10,590	24,000
	Subtotal	547,500	169,910	377,700
M1-M6	Mud Creek			
	Residential	62,510	18,920	43,590
	Commercial and Industrial	0	0	0
	Public and Other	8,910	750	8,165
	Agriculture 1/	10,590	3,700	6,900
	Subtotal	82,010	23,370	58,650
	Total Huron Plain	1,648,900	476,240	1,172,850
T11-T12	Tonawanda Creek: Meadville Road to City of Batavia			
	Residential	32,180	2,260	29,910
	Commercial and Industrial	3,870	380	3,490
	Public and Other	40,390	1,190	39,200
	Agriculture 1/	1,860	180	1,680
	Subtotal	78,300	4,010	74,280
B1-B5	City of Batavia			
	Residential	148,060	9,110	138,950
	Commercial and Industrial	119,220	220	119,000
	Public and Other	61,070	1,210	59,860
	Agriculture 1/	0	0	0
	Subtotal	328,350	10,540	317,810

Table S29 - Estimated Existing Average Annual Damages and Benefits (December 1975 Development Conditions and June 1980 Prices) (Cont'd)

Reach Number	Reach Name	Existing Average Annual Damages	BRCM Residual Average Annual Damages	BRCM Existing Average Annual Benefits
		$	$	$
T-13	Batavia to Alexander			
	Residential	32,220	0	32,220
	Commercial and Industrial	0	0	0
	Public and Other	11,070	0	11,070
	Agriculture 1/	1,610	1,600	10
	Subtotal	44,910	1,600	43,300
A-1	Alexander			
	Residential	21,970	21,970	0
	Commercial and Industrial	2/	2/	2/
	Public and Other	2/	2/	2/
	Agriculture 1/	3/	3/	3/
	Subtotal	21,970	21,970	0
A2-A3	Attica			
	Residential	29,940	29,940	0
	Commercial and Industrial	2/	2/	2/
	Public and Other	2/	2/	2/
	Agriculture 1/	3/	3/	3/
	Subtotal	29,940	29,940	0
	Total Erie Plain	503,470	68,060	435,410
	Total Tonawanda Creek Watershed			
	Residential	1,564,380	444,450	1,119,920
	Commercial and Industrial	129,730	1,970	127,730
	Public and Other	366,800	69,120	297,680
	Agriculture 1/	91,500	28,760	62,370
	Grand Total	2,152,400	544,300	1,608,030

1/ Agriculture development based on 1978 land use patterns.
2/ Included in residential.
3/ Not calculated as these reaches are upstream of the project.

(2) Area Redevelopment Benefits - In accordance with current guidance from WRC, no counties in Western New York qualify for Area Redevelopment Benefits. Cattaraugus and Allegany Indian Reservations located in Western New York are areas designated qualified for area redevelopment benefits.

It is not reasonable to assume that the labor pool employed in the construction of this project will include previously unemployed contract construction workers from either Indian Reservation. This assumption is reasonable because the commuting distance between each reservation and the Batavia, New York area, where actual construction will take place, is in excess of 50 miles. Also, there is no reliable means of public transportation between either Indian Reservation and the Batavia, New York project construction area.

(3) Existing Benefit-Cost Ratio: 1975 Development Conditions and June 1980 Prices - Inundation damage reduction benefits have been calculated for the BRC-Modified Plan and includes both urban damage reduction and agricultural damage reduction. A summary of the existing benefit-cost ratio for existing conditions is shown below.

Benefit-Cost Ratio: 1975 Development Conditions/1980 Prices

	$
Inundation Reduction	
Urban	1,545,300
Agriculture	62,700
Subtotal Inundation Reduction	1,608,000
Total Benefits	1,608,000
Average Annual Costs	2,043,000
Existing Benefit-Cost Ratio	0.79

b. Project Year One (1985) Development Conditions. Estimating damages and benefits at Project Year One (1985), and also for future years, raises the problem of relating Executive Order 11988 and the Corps regulation ER 1165-2-26, which sets forth Corps policy on implementing this Executive Order, to this analysis. ER 1165-2-26 specifies:

> "The Executive Order has an objective the avoidance, to the extent possible of long- and short-term adverse impacts associated with the occupancy and modification of the base flood plain and the avoidance of direct and indirect support of development in the base flood plain wherever there is a practicable alternative."

In order to apply the Executive Order to this analysis, it is necessary to evaluate urban development within the Tonawanda Creek Watershed.

(1) Urban Development in the Tonawanda Creek Watershed - For purposes of evaluating urban development, the Tonawanda Creek Watershed may be divided into two components: the eastern end of the lower watershed, hereafter

referred to as the EELW, and the remainder of the watershed. In Niagara County, the EELW includes all or most of the towns of Lockport and Pendleton, and significant portions of the town of Wheatfield and the city of North Tonawanda. In Erie County, it includes nearly all of the town of Clarence, significant portions of the towns of Amherst and Tonawanda, and the city of Tonawanda.

The EELW is strategically situated in a major growth corridor in the Buffalo SMSA, Erie and Niagara Counties. Most suburban development in the SMSA has been directed northward, onto the EELW and portions of the tributary Ellicott Creek Watershed, and eastward onto the Scajaquada and Cayuga Creek Watersheds. While Ellicott Creek is a tributary of Tonawanda Creek, it has been treated as a separate watershed, and a recommended plan of action for flood damage management is now under preparation. At present, most suburban growth is directed north onto the Ellicott Creek Watershed in the town of Amherst. The more distant towns in the EELW - Wheatfield, Pendleton, and Lockport in Niagara County, and Clarence in Erie County - are already experiencing significant amount of exurban, and in some cases, suburban development.

There are three reasons for assuming that future suburban development will continue to move into the northern growth corridor and eventually into the EELW itself during the project evaluation period.

First, four industrial communities bordering the Niagara River - the city of Buffalo, the industrialized eastern edge of the town of Tonawanda, the city of Tonawanda and its neighbor across Tonawanda Creek, the city of North Tonawanda, plus the city of Niagara Falls contain most of the employment opportunities within the Western New York Region. This employment, in turn, has generated substantial residential development in adjacent and nearby nonindustrial communities, including those comprising the EELW. Though this is not a rapidly growing industrial complex, it continues to generate residential housing demand, through replacement of aging housing stock and new family formation, a significant proportion of which will be met by residential construction on the nearby EELW.

Second, the EELW and adjacent areas have a municipal infrastructure which have been designed to accommodate substantial future development. This is particularly true for sanitary sewerage facilities, processing plants, and sewer lines, which probably are the single most important factor affecting the direction of future urban development in the Western New York Region. New sewer processing plants have recently been completed in the towns of Tonawanda and Wheatfield, and in the cities of Niagara Falls and North Tonawanda. New sewer lines are being or have recently been laid in the city of North Tonawanda, and in the towns of Amherst, Clarence, and Wheatfield. Further, expansion of the local highway network has made the EELW much more accessible to the industrial complex along its eastern edge than was the case a decade or more ago. This expansion includes development of: Williams Road, from I-190 at Niagara Falls to the Summit Mall in the town of Wheatfield; the Division Street Arterial connecting Colvin Boulevard in the town of Tonawanda to Division Street in North Tonawanda; and current improvement of Millersport Highway, which connects I-290 with Transit Road, the

major commercial strip development in the region. Finally, expanded services, exemplified by establishment of Summit Mall, commercial development along Transit Road (New York State 78), and establishment of Eastern Hills Mall, the largest regional shopping center in Western New York, have made the EELW an even more desirable location for future urban development. In fact, the developer of Summit Mall has recently initiated construction of a large-scale residential development adjacent to the Mall. Also, significant development continues to take place near Eastern Hills Mall.

Third, though not necessarily prohibited, growth in other directions is more restricted. Growth to the south has been severely restricted by the lack of adequate sewerage facilities. It is also inhibited by topography, the hilliness of the Alleghany Plateau, and the presence of the Lake Erie snowbelt. The snowbelt is an area of seasonal heavy snow storms located south of the city of Buffalo extending inland from Lake Erie to beyond East Aurora. Growth to the east, into the towns of Cheektowaga, Lancaster, and West Seneca has already been extensive, particularly in Cheektowaga and West Seneca. Growth in this direction must necessarily occur at ever increasing distances from downtown Buffalo. Growth to the west is impossible, given the presence of Lake Erie and the Canadian boundary.

Net impacts of the urban growth trends stated above assure that the EELW will experience urban development in the future, whether or not a flood plain management project is implemented on Tonawanda Creek. The pertinent questions are: (1) how much development will occur without the project; and (2) how much additional development, induced development, will occur as a result of implementation of the Selected Plan?

Appendix B of the 1976 Interim Feasibility Report addresses both questions. Table B36 of that report is a summary of the land use requirements in the future. These estimates were developed after evaluating a number of factors which would significantly affect future development such as regional population and employment trends; intraregional shifts in employment and population; local zoning ordinances and development philosophies; enforcement of floodproofing requirements; projected development of future municipal facilities; availability and projected development of sewer facilities and water supplies; soil conditions; and existing flood hazards. The evaluation included consultation with local officials and planners, including the Erie and Niagara Counties Regional Planning Board.

Since 1976, there have been some notable changes in the national situation which might change the projections of future land use patterns, particularly for the residential land demand component as it existed in 1976. Foremost among these have been the pronounced increase in new home prices and the sharp rise in home mortgage rates. Equally important has been the increase in gasoline costs and the shortages in supply. All of these factors have interacted to reduce the estimated demand for residential land on the flood plain of the EELW. For these reasons, the projected growth of residential development utilized in this supplemental analysis to Appendix B for the "without-project-condition" has been scaled down by 25 percent from earlier estimates.

It must be emphasized that all future development is based upon informed projections of future land use requirements under without project conditions. In other words, no induced development has been included in this analysis. The assumption that there will be no induced demand for land as a result of implementation of the Selected Plan is unrealistic when local geographic and land use trends within the watershd are considered, but complies with current policy in Executive Order 11988 and ER 1165-2-26. This conclusion is based on several observations: (1) short-term development since 1976 has already occurred on the flood plain without a project; (2) the Selected Plan, if implemented, will increase the attractiveness of the flood plain by substantially reducing the flood hazard and associated damages; and (3) there are no effective controls on economic growth within the watershed or New York State, other than enforcement of flood plain insurance (FIA) requirements, which can effectively prevent development from occurring. Flood plain insurance (FIA) requirements are not effective in restricting growth along Tonawanda Creek due to the character of the flood hazard. The existing and improved IRF on the EELW is only approximately 1 foot above the bankfull stage. Compliance with FIA requirements, either through landfill of residential property or floodproofing of other structures, is a relatively inexpensive process. Therefore, while this analysis assumes no induced development, it is to be expected that such development will occur. The only way to prevent induced development would be not to implement a project. However, not to implement this project would clearly not "reduce the hazard and risk associated with floods," and it would not "minimize the impact of floods on human safety, health and welfare" (ER 1165-2-26, 15 May 1979, par. 6b. and 6c.).

A final comment about the effect of future urban land use projections upon this analysis is warranted. Given the assumption of no induced development, the future urban development component of the analysis provides very limited benefits. As will be seen, total average annual future urban benefits account for less than 6 percent of the estimated total benefits for the BRCM plan. Therefore, project feasibility is not dependent upon future urban benefits.

(2) Inundation Reduction Damages and Benefits - Urban development has been projected to occur in the residential, commercial, and industrial sectors during the 1976-85 period. No growth has been projected in the public and other use sector for this period. Residential development has been projected to occur at a rate of 80 residential units per year with a total of 720 additional units to be constructed during this period. Commercial development is projected to occur at a rate of three units per year, and industrial development is projected at one unit every two years; this produces 27 commercial and 4.5 industrial units to be developed in the period. Though damages and benefits are presented for the aggregated category of commercial and industrial use, they were developed separately, then subtotaled due to the differing character of each category.

All development has been assumed to be in compliance with FIA regulations which require the lowest building opening to be at or above the IRF stage. Since short-term development will occur prior to Project Year One (1985), it has been situated at the existing condition, without project, IRF stage. All development has been located in the EELW portion of the flood plain since

this area is presently under the greatest short-term developmental pressures.

Damages were calculated by using a hypothetical but typical standard unit type within each category: residential, commercial, and industrial. Damages were separately estimated for contents and structures, and a stage damage relationship was developed for each structure type. For residential structures, the Buffalo District depth-damage curves were used to estimate structure and content damages. Tennessee Valley Authority depth-damage curves were used to develop structure and content damages for commercial and industrial structures. In this case, the same curve, a commercial depth-damage curve, was used for both structures. This was required since: (1) no industrial depth-damage curve was available locally; and (2) it was judged that a typical suburban industrial structure was very similar to the typical suburban commercial structure, though the former is usually larger. The relationship between structure and content values was verified based upon discussions with local building associations and contractors.

The damages described above are per unit damages. Incremental damages for each category were calculated by multiplying the appropriate per unit damage value by the number of units projected to be constructed on the flood plain during the 1976-85 period.

Incremental residual damages were estimated by calculating the amount of damages each unit would incur from floods above the IRF stage under improved conditions. In most, but not in all reaches of the EELW, there would be some damage to structures built at the existing IRF elevation during the 1976-85 period after implementation of the project in 1985. Incremental residual damages for each category were obtained by multiplying the appropriate residual damages value per unit by the number of units projected to be developed on the flood plain in the interim period. These remaining damages were then subtracted to estimate incremental inundation reduction benefits for the period 1976-1985.

Table S30 summarizes the 1976-85 inundation damages, incremental residual damages, and incremental benefits. Estimates are presented for all three variables for three time periods: 1975, 1976-85, and 1985. The flood plain has been subdivided into three components: Lower Tonawanda Creek, Ransom and Black Creeks, and the remainder of the basin. All development in this period is projected to occur within the first two subdivisions.

Short-term development (1976-85) makes a minor contribution to project benefits. Construction of the BRCM would result in incremental benefits of $33,100 (Table S30) and results primarily from growth of the residential sector.

(3) Benefit-Cost Ratio for 1985 Development Conditions - Short-term development has been forecasted for the lower portion of the watershed during the interval 1976-1985. Damages and benefits have been adjusted to reflect a greater number of units within the SPF zone. The value of agricultural output on the flood plain has been rising and will continue to rise. Basically this represents the regional component of a national secular trend of rising

Table S30 - Estimated Average Annual Urban Damages and Benefits, 1976-1985, June 1980 Prices

Reach Number		Residential 1975	Residential 1976-1985	Residential 1985	Commercial and Industrial 1975	Commercial and Industrial 1976-1985	Commercial and Industrial 1985	Public and Other 1975	Public and Other 1976-1985	Public and Other 1985	Total 1975	Total 1976-1985	Total 1985
		$	$	$	$	$	$	$	$	$	$	$	$
	BRCM												
T1-10	Lower Tonawanda Creek												
	Damages	833,800	41,700	792,100	3,640	3,700	7,340	139,000	0	139,000	976,500	45,400	1,021,900
	Residual Damages	240,500	11,700	228,800	450	1,800	2,250	29,300	0	29,300	270,300	13,500	283,800
	Benefits	593,300	30,000	563,300	3,190	1,900	5,090	109,700	0	109,700	706,200	31,900	738,100
RB1-4	Ransom and Black Creek												
	Damages	403,700	0	403,700	3,000	1,200	4,200	106,360	0	106,360	513,100	1,200	514,300
	Residual Damages	121,700	0	121,700	900	0	900	36,680	0	36,680	159,300	0	159,300
	Benefits	282,000	0	282,000	2,100	1,200	3,300	69,680	0	69,680	353,800	1,200	355,000
	Rest of Flood Plain												
	Damages	327,000	0	327,000	123,100	0	123,100	121,440	0	121,440	571,540	0	571,540
	Residual Damages	82,200	0	82,200	600	0	600	3,140	0	3,140	85,940	0	85,940
	Benefits	244,800	0	244,800	122,500	0	122,500	118,300	0	118,300	485,600	0	485,600
	Total Tonawanda Creek Flood Plain												
	Damages	1,564,400	41,700	1,606,100	129,700	4,900	134,600	366,800	0	366,800	2,060,800	46,600	2,107,400
	Residual Damages	444,500	11,700	456,200	1,970	1,800	3,770	69,100	0	69,100	515,600	13,500	529,100
	Benefits	1,119,900	30,000	1,149,900	127,630	3,100	130,730	297,700	0	297,700	1,545,200	33,100	1,578,300

Table S31 - Projected Demand for Urban Lands

	1985-1995		1995-2005		2005-2015		2015-2025		2025-2035		Future Change	
	Acres	Units	Acres	Units	Acres	Units	Acres	Units	Acres	Units	Acres 1/	Units
Residential	267	800	267	800	267	800	267	800	267	800	1,335	4,000
Commercial	5	10	10	20	15	30	20	40	25	50	75	150
Industrial	10	2	20	4	31	6	31	6	31	6	125	25
Public and Other	20	2	20	2	20	2	20	2	20	2	100	10
Total	302		317		333		338		343		1,635	

1/ Change in acreage for 1985-2035 *does not* equal the sum of acreage across the five decades due to rounding errors.

agricultural productivity and output. As illustrated in Table S24. Agricultural benefits are projected to rise to $64,730 in project base year (1985). A benefit-cost ratio for 1985 conditions of development has also been developed and is summarized below. Short-term benefits are relatively small and do not significantly alter the 1975 level of economic feasibility.

	$
Inundation Reduction	
Urban	1,578,300
Agriculture	64,730
Subtotal	1,643,030
Total Benefits	1,643,030
Average Annual Costs	2,043,000
Existing Benefit-Cost Ratio	0.80

S3.2 Future Development Conditions

Future urban development has been anticipated to occur on the flood plain without implementation of a plan. For the 50-year forecast period, 1985-2035, development has been projected for all three urban sectors: residential, commercial and industrial, and public and other use. Acreage, number of units, and timing of this development by decade are presented in Table S31.

Future urban growth is expected to locate in the lower reaches of the watershed, primarily in T1-T4 and RB1-RB4. This growth is a result of developmental pressures originating along the northern perimeter of the Buffalo Metropolitan Area. All units to be constructed in the flood plain are assumed to have their lowest opening at or above the improved IRF elevation.

One acre of residentially zoned land will support three residential units and 80 units per year have been projected for residential development. Public and other use development is also projected to occur at a constant rate. Assuming one public and other use structure per 10 acres of such land use, two units are projected to be developed in each decade of the planning period. Since suburbanization of commercial and industrial activities has characteristically lagged behind population growth, a deferred rate of development has been adopted for this sector. Though aggregated into one sector, projections were independently prepared for commercial and for industrial use. For commercial development, two units are projected for each acre of land; thus the 75 acres projected will allow an additional 150 commercial units. For industrial development, one unit is projected for each 5 acres, thus the 125 acres of industrial land will support 25 industrial units.

All future urban development is assumed to be in compliance with FIA regulations. Since all future development will by definition occur after Project Year One, all structures are assumed to have their lowest openings floodproofed to or built above the improved IRF stage.

a. Inundation Reduction Effects.

Impacts of this development on project feasibility have been investigated by measuring its contribution to average annual damages and benefits. Construction of hypothetical residential units which would have features similar to structures expected to be built in the future (i.e., two-story, wood frame, medium-value houses with basements) will alter the 1975 stage damage curves as shown in Plates B9 through B39. Undiscounted damages rise over time since this development is protected only to the improved IRF elevation but are still susceptible to damages from events with an exceedance frequency above 1.0 percent. However, since the slope of the stage frequency curves under existing and improved conditions in the downstream reaches are almost parallel, residual damages per unit do not vary significantly between post-project (improved) conditions and the unit damages sustained by these structures if they were built at the existing IRF elevation. Future units will incur no greater economic losses per unit under improved conditions than short-term development now experiences on an average annual basis. A summary of undiscounted damages and benefits are summarized in Table S32.

b. Affluence Factor Benefits.

(1) Residential Affluence - The dollar value of residential contents has been projected to grow at a rate equal to the projected average annual growth of personal income per capita in the Buffalo Economic Area (BEA-009). Growth in residential contents was terminated when the value of contents equaled 75 percent of the value of residential structures; this constraint occurs at Project Year 27 (2012). Beyond this date, the value of residential contents were held constant throughout the remainder of the planning period.

To provide a base for projecting growth in residential contents, it was necessary to allocate existing inundation reduction benefits between residential structures and contents. Using information obtained from the 1975 damage survey, it has been estimated that damage reduction of residential contents are approximately $257,600 (Table S33). Assuming a 2.7 percent annual compound growth rate for personal income per capita, the rate at which OBERS forecasts personal income per capita to grow in the nonmetropolitan portion of the Buffalo Economic Area, benefits attributable to contents increases to $336,200 in project year 1. Residential content benefits are projected to increase for 27 years reference economic base year at which point content value reaches 75 percent of structural value. In project year 27 (2012) residential content benefits will increase to $690,300. This produces an undiscounted growth of content benefits of $354,100. Discounting these values by the appropriate average annual equivalent factor (project interest rate of 7.375 percent, 100-year project life, and compound growth for 27 years) produces discounted average annual residential affluence factor benefits of $146,300 based on June 1980 prices (Table S33).

Table S32 - Future Undiscounted Urban Flood Inundation Damages and Benefits, June 1980 Prices

BRCM	P1 1985	P10 1995	P20 2005	P30 2015	P40 2025	P50 2035
	$	$	$	$	$	$
Residential						
Existing Damages	1,606,100	1,652,500	1,698,900	1,745,300	1,791,700	1,838,100
Residual Damages	456,200	502,600	549,000	595,400	641,800	688,200
Benefits	1,149,900	1,149,900	1,149,900	1,149,900	1,149,900	1,149,900
Commercial and Industrial						
Existing Damages	134,600	136,800	143,500	156,800	177,700	206,900
Residual Damages	3,770	5,970	12,670	25,970	46,870	76,070
Benefits	130,830	130,830	130,830	130,830	130,830	130,830
Public and Other						
Existing Damages	366,800	368,200	369,600	371,000	372,400	373,800
Residual Damages	69,100	70,500	71,900	73,300	74,700	76,100
Benefits	297,700	297,700	297,700	297,700	297,700	297,700
Total						
Existing Damages	2,107,400	2,157,400	2,211,900	2,273,000	2,341,700	2,418,700
Residual Damages	529,100	579,100	633,600	694,700	763,400	840,400
Benefits	1,578,300	1,578,300	1,578,300	1,578,300	1,578,300	1,578,300

Table S33 - Average Annual Residential Affluence Factor Benefits (June 1980 Prices)

	Average Annual Benefits (1975)	Compound Annual Rate of Growth 1/	Undiscounted Benefits at P_1	Undiscounted Benefits at P_{27}	Incremental Benefits $P_1 - P_{27}$	Average Annual Equivalent Factor 2/	Average Annual Residential Affluence Factor Benefits
	$		$	$	$		$
BRCM							
Structures	862,300	0	862,300	862,300	0	-	-
Contents	257,600	2.7	336,200	690,200	354,100	.4131	146,300
Total	1,119,900		1,198,500	1,552,600	354,100		146,300

1/ The rate at which personal income per capita has been projected to grow in the nonmetropolitan part of BEA Economic Area 004. OBERS, Table 1, Vol. 6, p. 14.

2/ 100 project life; 7.375 percent project interest rate and 34 years of compound growth.

(2) Commercial Affluence - Commercial activity is most commonly measured by retail sales.

The constant dollar value of retail sales in Genesee County, which contains the bulk of commercial activity in the watershed, has stagnated in recent years. In constant dollars, the volume of retail sales increased at an annual rate of only .3 percent per year between the last two Census of Business dates, 1967 and 1972. Since the level of growth in retail sales has been so low, and since future levels of commercial sales cannot be projected with any certainty, no commercial affluence benefits were credited to the proposed project.

(3) Total Affluence Factor - Affluence factor benefits for the BRCM plan are summarized in Table S34.

Table S34 - Summary of Affluence Factor Benefits (June 1980 prices)

	BRCM
	$
Residential	146,300
Commercial	0
Total	146,300

c. Site Development Benefits.

Site development benefits are savings in floodproofing costs, net of the increase in residual damages, that would have been incurred by future development but which would be avoided as a result of a plan of improvement. For commercial, industrial, and public and other use facilities, the floodproofing costs saved are generally the cost of floodproofing the structure to its lowest opening above the 100-year (IRF) flood elevation. For residential structures, the floodproofing costs saved are generally landfill savings as residential construction materials and techniques cannot usually withstand significant horizontal pressures exerted by moving flood waters.

(1) Landfill Savings - Landfill savings have been defined as the difference between the cost of landfill required without a project and the cost of landfill material required if a plan of improvement is implemented. Under existing Flood Insurance Administration regulations, new construction or substantial improvements to existing structures within the limits of the designated 100-year flood plain are required to have their lowest structural opening elevated to or above the 100-year flood stage, or, together with attendant utility or sanitary facilities, be floodproofed up to the level of the elevation of the 100-year flood.

It has been estimated that materials excavated from an average residential basement, 38 by 40 by 6 feet in depth, would provide approximately the first

foot of required fill on the average residential lot. For this reason, it has been assumed that landfill savings will occur only in those reaches where the IRF stage under improved conditions is projected to decrease by more than 1 foot in comparison to the IRF stage under existing conditions. An examination of the stage frequency curves for existing and improved conditions for each reach indicates this condition would be met in only seven reaches Table S35). In all other reaches, the decrease in the IRF stage is 1.0 foot or less. Since almost no residential and related development has been projected for these upstream reaches, no landfill savings were credited to the plan of improvement.

Table S35 - IRF Stage Reduction for Selected Reaches

Reach 1/	Stage Reduction in Feet BRCM
T-3	1.8
T-11	2.4
T-12	2.3
B1	2.5
B2 and 3	2.2
B4 and 5	2.1
T-13	2/

1/ Includes only those reaches that have more than 1.0-foot reduction in IRF stage.
2/ Improved flood water elevations are above existing due to storage effect of reservoir compound.

(2) Floodproofing Costs Avoided - Further investigation into these future urban benefits indicated that the equivalent annual discounted values were small when discounted at the project interest rate and converted to an average annual series. Projections of future flood plain development (Table S31) and the small reduction in flood stage between the existing and improved IRF elevations in the lower watershed combine to limit discounted annual future site development savings to about $10,000.

Residual damages were also estimated to rise over time as a result of the susceptibility of future units to floods above the improved IRF. These damages per unit were estimated by constructing stage damage relationships for structures considered to be representative of future flood plain units in terms of value, physical size, and construction materials for residential, commercial and industrial, and public and other units. Damages per unit were based upon that portion of the improved stage frequency curve for floods beyond the 1.0 percent exceedence frequency and depth-damage curves. The damage frequency relationship was integrated to obtain average annual damages

per unit and this estimate was multiplied by the number of units anticipated by the end of the forecast period (2030). This absolute increase was converted to its equivalent annual value and summed for all three urban categories.

Future incremental discounted average residual damages are relatively small due to the effect of the project interest rate and the low rate of growth of floodprone structures. Future incremental average annual residual damages were approximately the same as the site development savings.

Site development savings for future urban development are offset by the increase in residual damages, therefore, no net future site development benefits have been credited to the BRCM plan.

d. Summary of Total Urban Benefits - Residential affluence benefits are the only category of future urban benefits credited to project feasibility. A summary of project benefits is included in Table S36.

Table S36 - Summary of Total Urban Benefits

	$
1. Existing Conditions	
(a) Inundation Reduction 1/	1,578,300
Subtotal Existing Conditions	1,578,300
2. Future Conditions	
(a) Affluence Benefits	146,300
Subtotal Future Conditions	146,300
3. Total Urban Benefits	1,724,600

1/ 1985 conditions of development.

The proposed plan of improvement (BRCM) will result in benefits to existing occupants and users of floodprone areas by reducing the extent of economic losses that now occur on an annual basis. In addition, existing occupants, primarily farm operators and owners, may also benefit from intensified levels of activity in the flood plain.

A summary of total existing and future benefits have been summarized in Table S37.

Table S37 - Summary of Total Benefits
June 1980 Prices
1985 Conditions of Development

	$
1. Existing Conditions	
a. Agriculture Damage Reduction	64,700
b. Urban Damage Reduction	1,578,300
c. Area Redevelopment	-
Subtotal Existing Benefits	1,643,000
2. Future Conditions	
a. Agricultural Intensification	824,400
b. Projected Growth of Future Agricultural Benefits	3,800
c. Urban Affluence	146,300
Subtotal Future Benefits	974,500
3. Total Benefits for BRCM	2,617,500
4. Average Annual Costs 1/	2,043,000
5. Net Benefits	574,500
6. Benefit-Cost Ratio	1.28

1/ Includes Operation and Maintenance.

S3.3 Sensitivity Study - Upper Reservoir Only

Construction of the BRCM is contingent upon economic feasibility, public acceptance of a reservoir compound upstream of Batavia, NY, and local acceptance by farm operators and other land owners of project features (i.e., proposed alignment of the reservoir structure, seasonal inundation of land in T-13, and rights-of-way to be granted for operation and maintenance). If the lower reservoir component of the BRCM cannot be constructed due to environmental, social, or institutional constraints, the upper reservoir component may still be feasible by itself. This alternative would have a lower construction cost and also result in less total benefits to the urban and agricultural sectors as a result of a lower degree of protection.

The results of a general sensitivity study for the construction of the upper reservoir only are summarized below. The evaluation is based on the same methodologies developed for the BRCM, adjusted for the reduction in level of protection or extent of stage reduction as shown in stage frequency curves (Plates A88 to A121).

a. Agricultural Benefits.

(1) Inundation Reduction For Existing Land Use - Stage damage curves, developed during the evaluation of the BRCM, were used in conjunction with improved stage-frequency curves to derive existing and improved damages, residual damages, and benefits. Table S38 is a summary of damages and benefits for an upper reservoir only.

Table S38 - *Summary of Existing Average Annual Agricultural Damages and Benefits for Upper Reservoir Only (1980 Prices and 1978 Conditions of Development)*

Reaches	Existing Damages	Residual Damages	Benefits
	$	$	$
T1-T10	43,000	21,700	21,300
RB1-RB4	34,400	19,100	15,300
M1-M6	10,600	4,500	6,100
T11-T12	1,900	400	1,500
B1-B5	0	0	0
T13	1,600	400	1,200
A1-A3 1/	-	-	-
Total 2/	91,500	46,100	45,400

1/ No damages have been calculated for these reaches as they are located upstream of the project site.

2/ Totals may not add due to rounding.

(2) Agricultural Intensification - Future Land Use - Implementation of an upper reservoir only may also induce existing farm operators to change their existing land use patterns depending upon the degree that early spring floods can be reduced or eliminated. This economic impact was measured by a methodology similar to the one developed for the BRCM and reduced in proportion to the reduction in return period for annual flood events in downstream reaches. Return period measurements were considered as an indicator of the response of local farm operators to the reduced degree of protection in downstream reaches. The revised estimate of the net annualized increase in agricultural profitability is $619,150.

Future agricultural residuals are also expected to increase over time as the crop mix is upgraded to include higher value crops or conversion of vacant land into cropland. Additional investments of materials (labor, seed, fertilizers, and herbicides) per acre result in residual losses increasing over the expected response period (10 years after project completion) and continuing at that level for the remainder of the project life. Incremental residual damages of $11,100 were subtracted from the forecasted increase in gross revenues. Net intensification benefits credited to construction of the upper reservoir only are $608,050.

(3) Projected Long-Term Growth in Agricultural Earnings - OBERS forecasts of agricultural output and earnings rise over time and reflect a long-term secular trend of increasing productivity and technological improvements.

Future incremental agricultural earnings are developed by applying the OBERS forecasted earnings growth rate to the estimate of annual damage reduction. Incremental gains are shown below along with the discounted equivalent annual increase. As previously stated 1978 conditions of development are assumed to approximate 1980 development conditions.

As illustrated in Table S39 agricultural benefits are projected to increase to 46,870 in project base year (1985) and continue to rise to $53,760 in project year 50 (2035).

Table S39 - Discounted Future Agricultural Benefits
(Upper Reservoir Only)

Year	Benefit 1/	Increment	Net Increase 2/	Average Annual Equiv. Factor	Present Worth of $1/Period	Present Worth Factor	Amortization Factor	Discounted Average Annual Benefits 3/
1985	46,870							
		1985-1995	2,530	.7410	-	-	-	1,870
1995	49,400							
		1995-2005	1,705	.7408	13.53689	.49087	.07381	620
2005	51,105							
		2005-2015	870	.7404	13.51361	.24096	.07381	150
2015	51,975							
		2015-2025	885	.7395	13.46621	.11828	.07381	80
2025	52,860							
		2025-2035	900	.7376	13.36963	.05806	.07381	40
2035	53,760							
Total								2,760

1/ Assumes straight line growth between points

2/ Net increase in the value of agricultural benefits attributed to national productivity gains

3/ Interest rate of 7-3/8 percent and 100-year project life.

b. Urban Benefits.

(1) Existing Condition of Development

(a) Inundation Reduction (1975) - Table S40 includes a summary of the damage reduction benefits attributed to construction of an upper reservoir only. Average annual benefits are estimated to be $1,233,690.

Table S40 - Estimated Existing Average Annual Damages and Benefits (December 1975 Development Conditions and June 1980 Prices)

Reach Number	Reach Name	Existing Average Annual Damages	BRCM Residual Average Annual Damages	BRCM Existing Average Annual Benefits
		$	$	$
T1-T10	Lower Tonawanda Creek			
	Residential	833,800	392,960	440,840
	Commercial and Industrial	3,640	1,750	1,890
	Public and Other	139,000	52,880	86,120
	Agriculture 1/	42,950	21,700	21,300
	Subtotal	1,019,400	469,290	550,150
RB1-RB4	Ransom and Black Creek			
	Residential	403,700	211,440	192,260
	Commercial and Industrial	3,000	1,380	1,620
	Public and Other	106,360	50,520	55,840
	Agriculture 1/	34,430	19,100	15,300
	Subtotal	547,500	282,440	268,020
M1-M6	Mud Creek			
	Residential	62,510	23,840	38,670
	Commercial and Industrial	0	0	0
	Public and Other	8,910	2,250	6,660
	Agriculture 1/	10,590	4,500	6,100
	Subtotal	82,010	30,590	51,430
	Total Huron Plain	1,648,900	782,320	869,600
T11-T12	Tonawanda Creek: Meadville Road to City of Batavia			
	Residential	32,180	6,[illegible]	25,270
	Commercial and Industrial	3,870	730	3,140
	Public and Other	40,390	7,900	32,490
	Agriculture 1/	1,860	400	1,500
	Subtotal	78,300	15,940	62,400
B1-B5	City of Batavia			
	Residential	148,060	29,840	118,220
	Commercial and Industrial	119,220	17,860	101,360
	Public and Other	61,070	10,930	50,140
	Agriculture 1/	0	0	0
	Subtotal	328,350	58,630	269,720

Table S40 - Estimated Existing Average Annual Damages and Benefits (December 1975 Development Conditions and June 1980 Prices) (Cont'd)

Reach Number	Reach Name	Existing Average Annual Damages	BRCM Residual Average Annual Damages	BRCM Existing Average Annual Benefits
		$	$	$
T-13	Batavia to Alexander			
	Residential	32,220	7,160	25,060
	Commercial and Industrial	0	0	0
	Public and Other	11,070	2,360	8,710
	Agriculture 1/	1,610	400	1,200
	Subtotal	44,910	9,920	34,970
A-1	Alexander			
	Residential	21,970	21,970	0
	Commercial and Industrial	2/	2/	2/
	Public and Other	2/	2/	2/
	Agriculture 1/	3/	3/	3/
	Subtotal	21,970	21,970	0
A2-A3	Attica			
	Residential	29,940	29,940	0
	Commercial and Industrial	2/	2/	2/
	Public and Other	2/	2/	2/
	Agriculture 1/	3/	3/	3/
	Subtotal	29,940	29,940	0
	Total Erie Plain	503,470	136,400	367,070
	Total Tonawanda Creek Watershed			
	Residential	1,564,380	724,060	840,320
	Commercial and Industrial	129,730	21,720	108,010
	Public and Other	366,800	126,840	239,960
	Agriculture 1/	91,500	46,100	45,400
	Grand Total	2,152,410	918,720	1,233,690

1/ Agriculture development is for 1978.
2/ Not calculated as these reaches are upstream of the project.
3/ Included in residential.

(b) Benefit-Cost Ratio (1975 Conditions of Development, June 1980 Prices) - Existing average annual benefits have been defined as inundation reduction benefits. Average annual inundation reduction benefits are $1,233,690. Average annual costs for an upper reservoir only are $1,355,000. The benefit-cost ratio is .92.

(2) Future Development

(a) Inundation Reduction (1985) - Short-term development of floodprone areas is expected by the end of project construction. Intermediate development (1976-1985) is assumed to comply with FIA regulations with lowest openings at or above the existing (unimproved) IRF elevation. This development will alter the present stage damage curves and increase residual damages and benefits by an amount shown in Table S41. These additional damages and benefits do not significantly alter project feasibility above the level attained by the 1975 damage survey. As illustrated in Table S39, agricultural benefits increase to $46,870 in project base year (1985) due to long-term secular trend of increasing productivity and technological improvements.

(b) Affluence Factor Benefits

(1) Residential - Damage surveys conducted in 1975 were used to estimate the proportion of inundation reduction benefits attributed to an upper reservoir only. Residential content benefits, estimated at $193,300, will increase to $252,300 by Project Year One. Forecasts of per capita income developed by OBERS for the Buffalo Economic Area are based upon a long-term annual compound growth rate of 2.7 percent. Undiscounted content benefits will increase to $518,000 by the year 2012, the approximate date when the value of contents in the flood plain will reach 75 percent of the value of residential structures. Discounted average annual residential affluence benefits of $109,700 are summarized in Table S42 and have been credited to an upper reservoir only.

Table S41 - Estimated Average Annual Urban Damages and Benefits, 1976-1985, June 1980 Prices

	Residential			Commercial and Industrial			Public and Other			Total		
	1975	1976-1985	1985	1975	1976-1985	1985	1975	1976-1985	1985	1975	1976-1985	1985
	$	$	$	$	$	$	$	$	$	$	$	$
<u>Upper Reservoir Only</u>												
<u>Lower Tonawanda Creek</u>												
Damages	833,800	41,700	875,500	3,640	3,700	7,340	139,000	0	139,000	976,440	45,400	1,021,840
Residual Damages	392,960	19,600	412,560	1,750	2,700	4,450	52,880	0	52,880	447,590	22,300	469,890
Benefits	440,840	22,100	462,940	1,890	1,000	2,890	86,120	0	86,120	528,850	23,100	551,950
<u>Ransom and Black Creek</u>												
Damages	403,700	0	403,700	3,000	1,200	4,200	106,360	0	106,360	513,060	1,200	514,260
Residual Damages	211,440	0	211,440	1,380	200	1,558	50,520	0	50,520	263,340	200	639,540
Benefits	192,260	0	192,260	1,620	1,000	2,620	55,840	0	55,840	249,720	1,000	250,720
<u>Rest of Flood Plain</u>												
Damages	326,880	0	326,880	123,090	0	123,090	121,440	0	121,440	571,410	0	571,410
Residual Damages	119,660	0	119,660	18,590	0	18,590	23,440	0	23,440	161,690	0	161,690
Benefits	207,220	0	207,220	104,500	0	104,500	98,000	0	98,000	409,720	0	409,720
<u>Total Tonawanda Creek Flood Plain</u>												
Damages	1,564,380	41,700	1,606,080	129,730	4,900	134,630	366,800	0	366,800	2,060,910	46,600	2,107,510
Residual Damages	724,060	19,600	743,660	21,720	2,900	24,620	126,840	0	126,840	872,620	22,500	895,120
Benefits	840,320	22,100	862,420	108,010	2,000	110,010	239,960	0	239,960	1,188,290	24,100	1,212,390

Table S42 - Average Annual Residential Affluence Benefits (June 1980 Prices)

	Average Annual Benefits (1975)	Compound Annual Rate of Growth 1/	Undiscounted Benefits at P_1	Undiscounted Benefits at P_{27}	Incremental Benefits $P_1 - P_{27}$	Average Annual Equivalent Factor 2/	Average Annual Residential Affluence Factor Benefits
	$		$	$	$		$
Structures	647,000	0	647,000	647,000	0	-	-
Contents	193,300	2.7	252,300	518,000	265,700	.4131	109,700
Total	840,300		899,300	1,165,000	265,700		109,700

1/ The rate at which personal income per capita has been projected to grow in the nonmetropolitan part of BEA Economic Area 004. OBERS, Table 1, Vol. 6, p. 14.

2/ 100 project life; 7.375 percent project interest rate and 27 years of compound growth.

(2) Commercial - A low rate of growth in retail sales between the last two Census of Business dates (1967 and 1972) for Genesee County was the basis for not projecting future commercial inundation reduction benefits.

c. Site Development Benefits.

(1) Landfill Savings - Examination of the stage-frequency curves for existing and improved conditions for an upper reservoir only indicated that only minimal reductions in IRF flood stages would occur in downstream reaches. Seven reaches with the greatest stage reduction are summarized in the table below.

Reach 1/	Stage Reduction (in feet)
T-11	1.3
T-12	1.1
B-1	1.3
B2 & B3	1.2
B4 & B5	1.1
T-13	1.3

1/ All other reaches will have one-foot or less of flood stage reduction.

It has been assumed that there would be potential landfill savings only for those downstream reaches which also have more than 1.0-foot stage reduction for the IRF. Most reaches that will have 1.0-foot or more in stage reduction are in the upstream portions of the flood plain where developmental pressures are lowest. Therefore, no landfill savings have been credited to an upper reservoir only.

(2) Floodproofing Costs Avoided - Savings in incremental floodproofing costs for the commercial, industrial, and public and other sectors, have been approximated as equal to those savings estimated for the BRCM. This approach was based upon the similarity in flood stage reduction between each plan. Residual damages for incremental commercial, industrial, and public and other units, were estimated and were approximately equal to the discounted floodproofing savings. Therefore, no future site development savings have been credited to an upper reservoir only.

d. Total Benefits. Construction of the upper reservoir only is economically justified based on existing inundation reduction benefits and future urban and agricultural benefits. A summary of the benefits are included in Table S43.

Table S43 - Summary of Benefits for Upper Reservoir

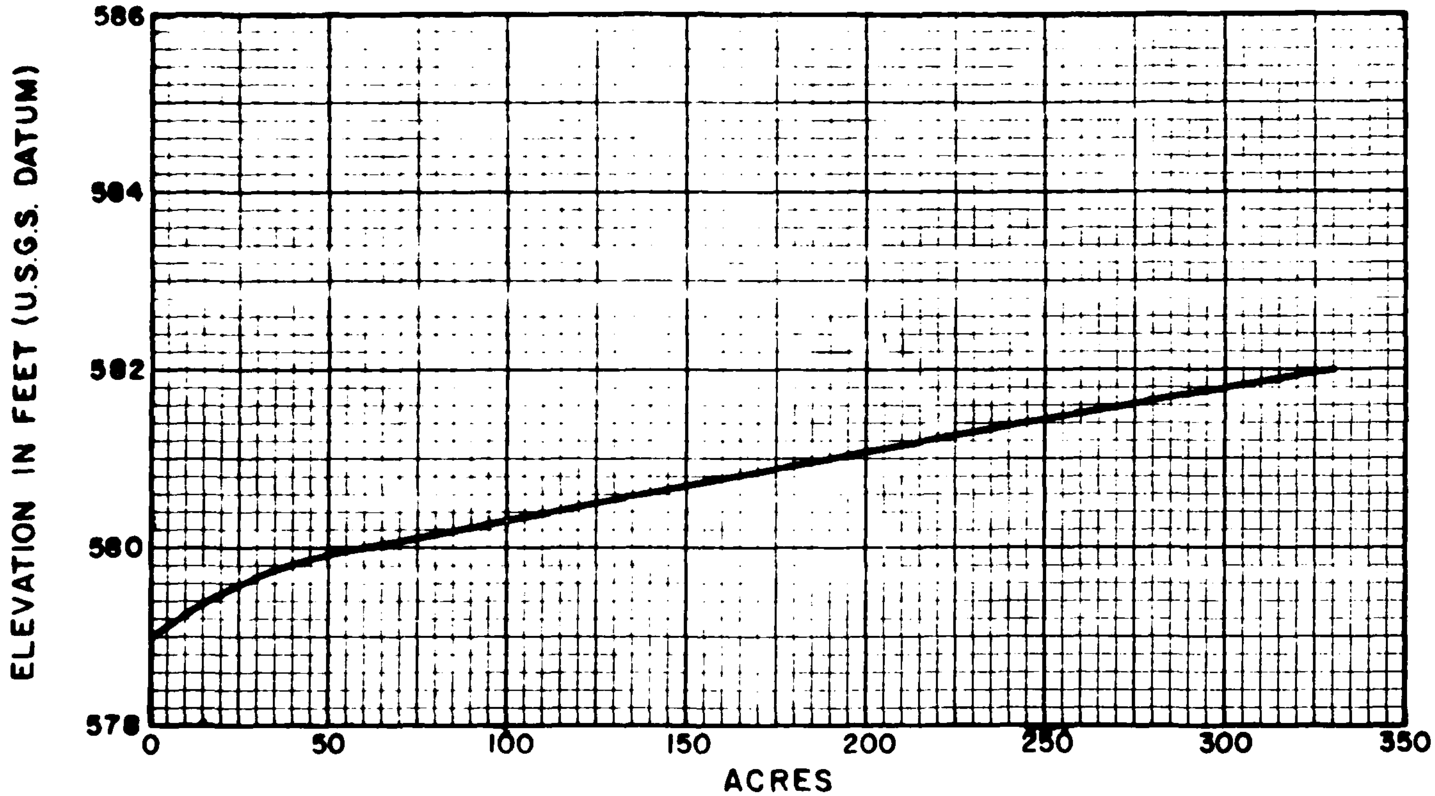
	$
Agriculture	
(a) Inundation reduction	46,870
(b) Intensification	608,050
(c) Long-term productivity gains	2,760
Subtotal Agriculture	657,680
Urban	
(a) Inundation reduction 1/	1,212,390
(b) Affluence	109,700
Subtotal Urban	1,322,090
Total Benefits	1,979,770
Total Average Annual Costs 2/	1,335,000
Net Benefits	644,770
Benefit-Cost Ratio	1.48

1/ 1985 conditions of development. June 1980 prices.
2/ Includes operation and maintenance.

S4. SUMMARY AND CONCLUSIONS

S4.1 Summary of Project Benefits and Costs

A summary of project benefits are included in Table S37. Total average annual benefits are estimated at $2,617,500. Total average annual costs for the BRCM are $2,043,000. Detailed estimates of the construction items included in the Selected Plan are shown in Appendix D. Construction of the BRCM maximizes the use of the natural storage available upstream of Batavia, NY, and results in a flood damage management plan that maximizes net benefits and satisfies the planning objectives stated in the Main Report.

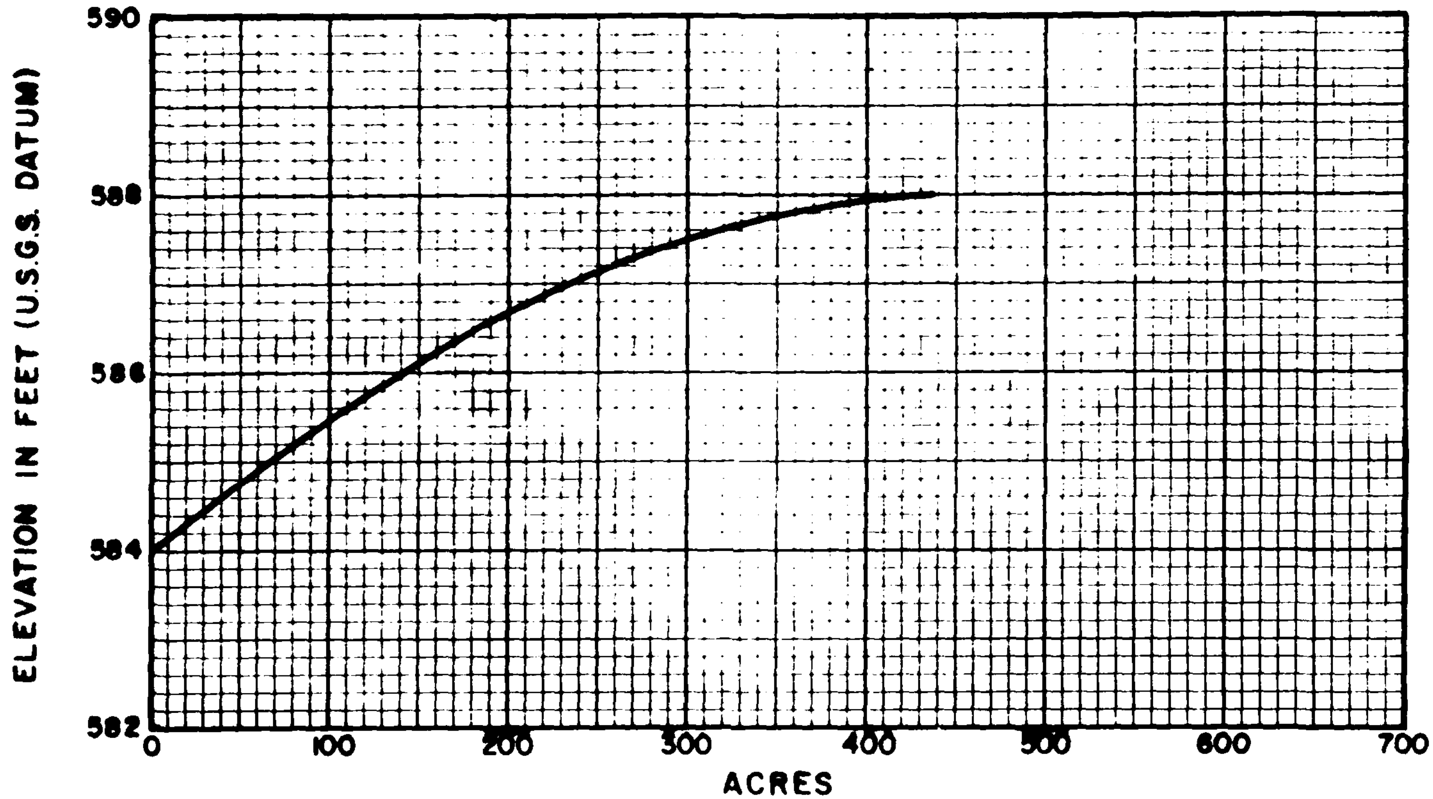


TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

TONAWANDA CREEK
INDEX POINT T-3 AT MILE 12.8

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED



TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

TONAWANDA CREEK
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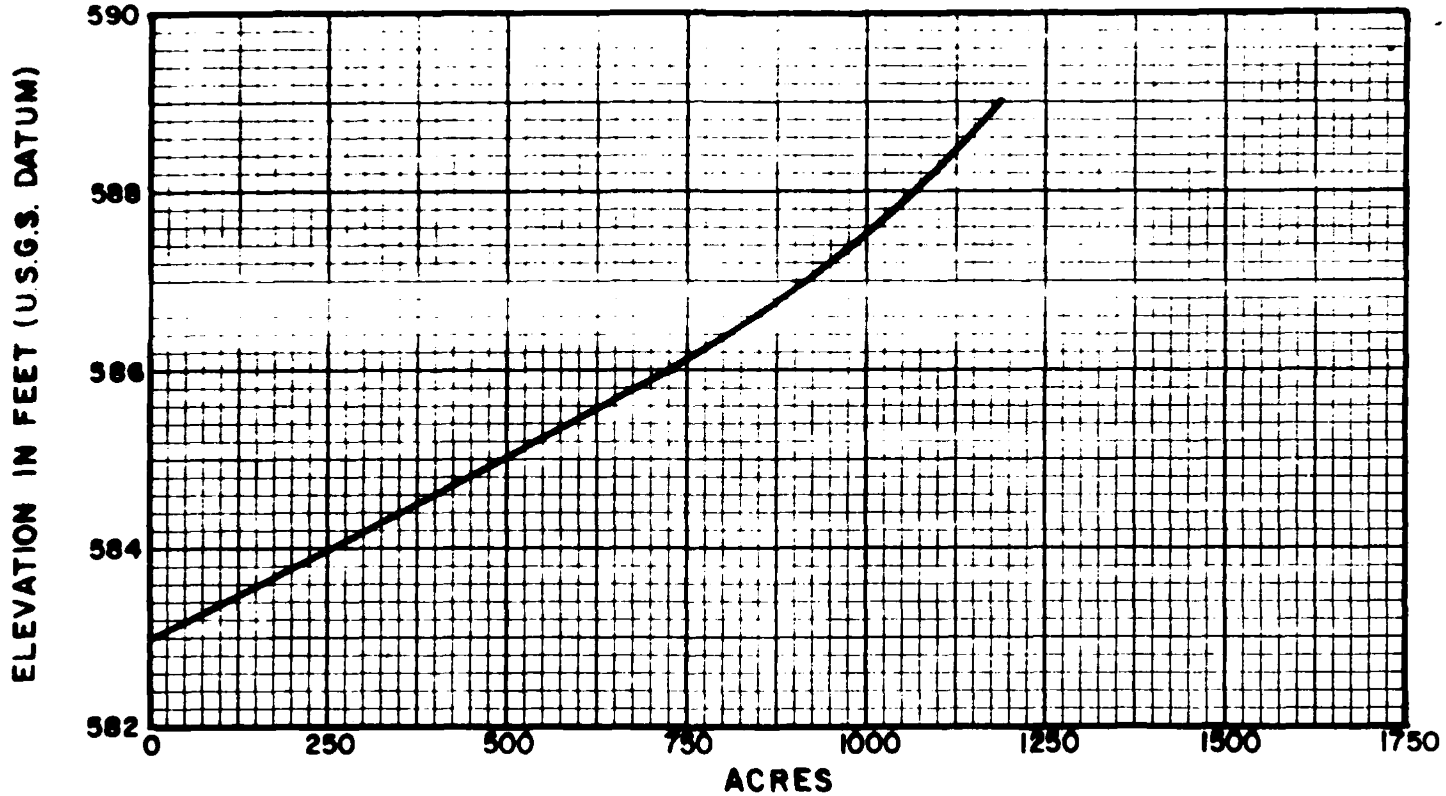

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

TONAWANDA CREEK
INDEX POINT T-5 AT MILE 17.4

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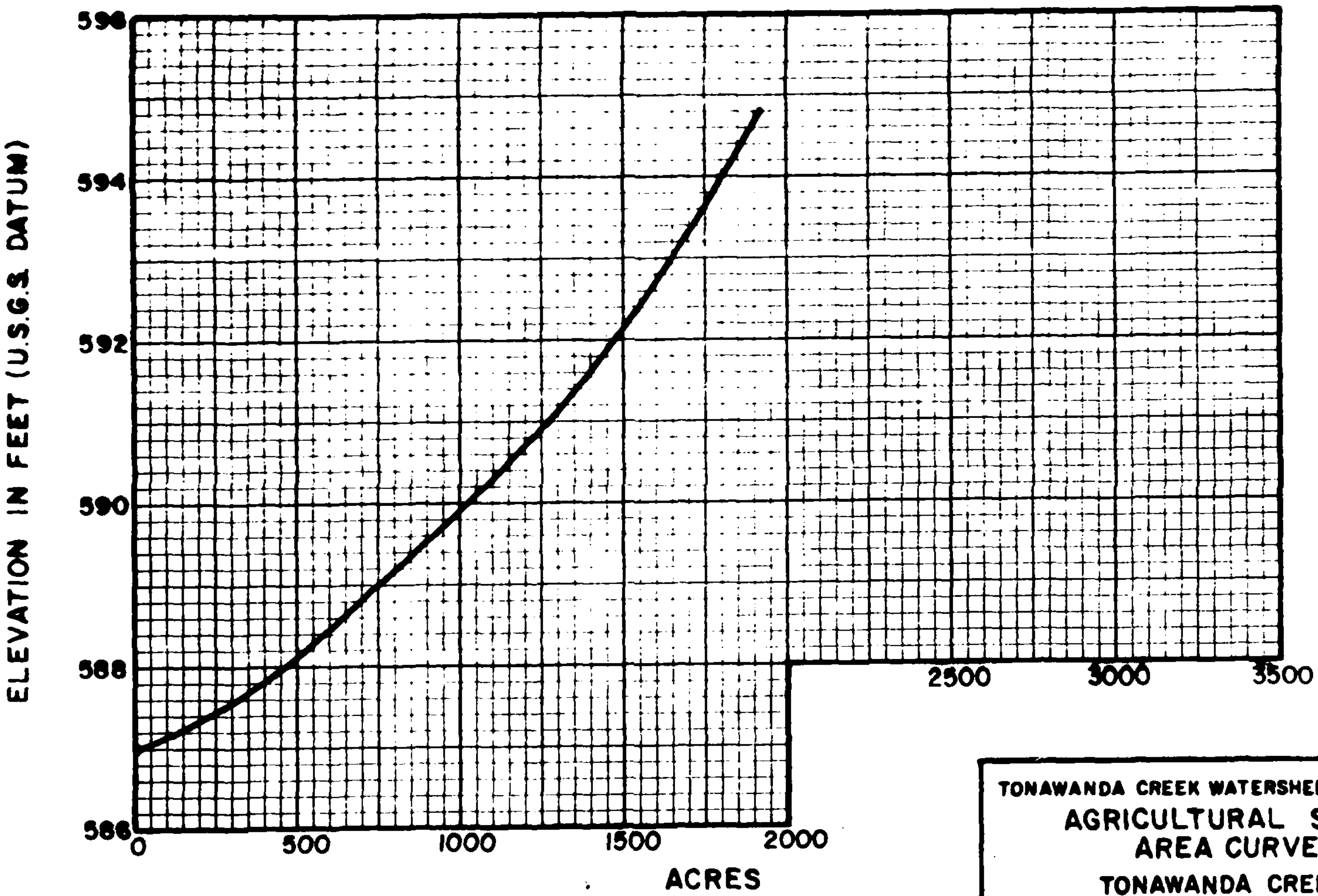

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

TONAWANDA CREEK
INDEX POINT T-6 AT MILE 22.8

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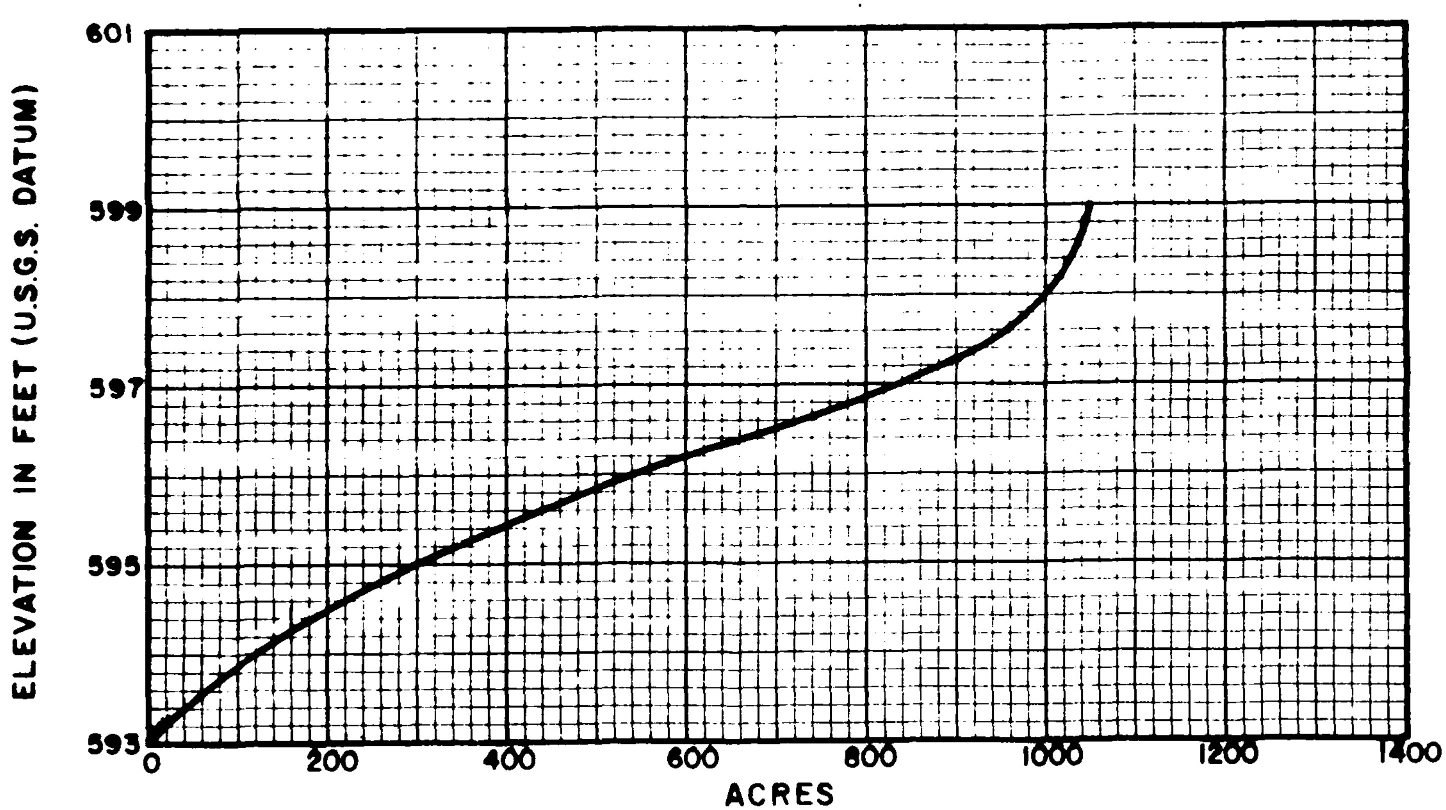

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

TONAWANDA CREEK
INDEX POINT T-7 AT MILE 28.0

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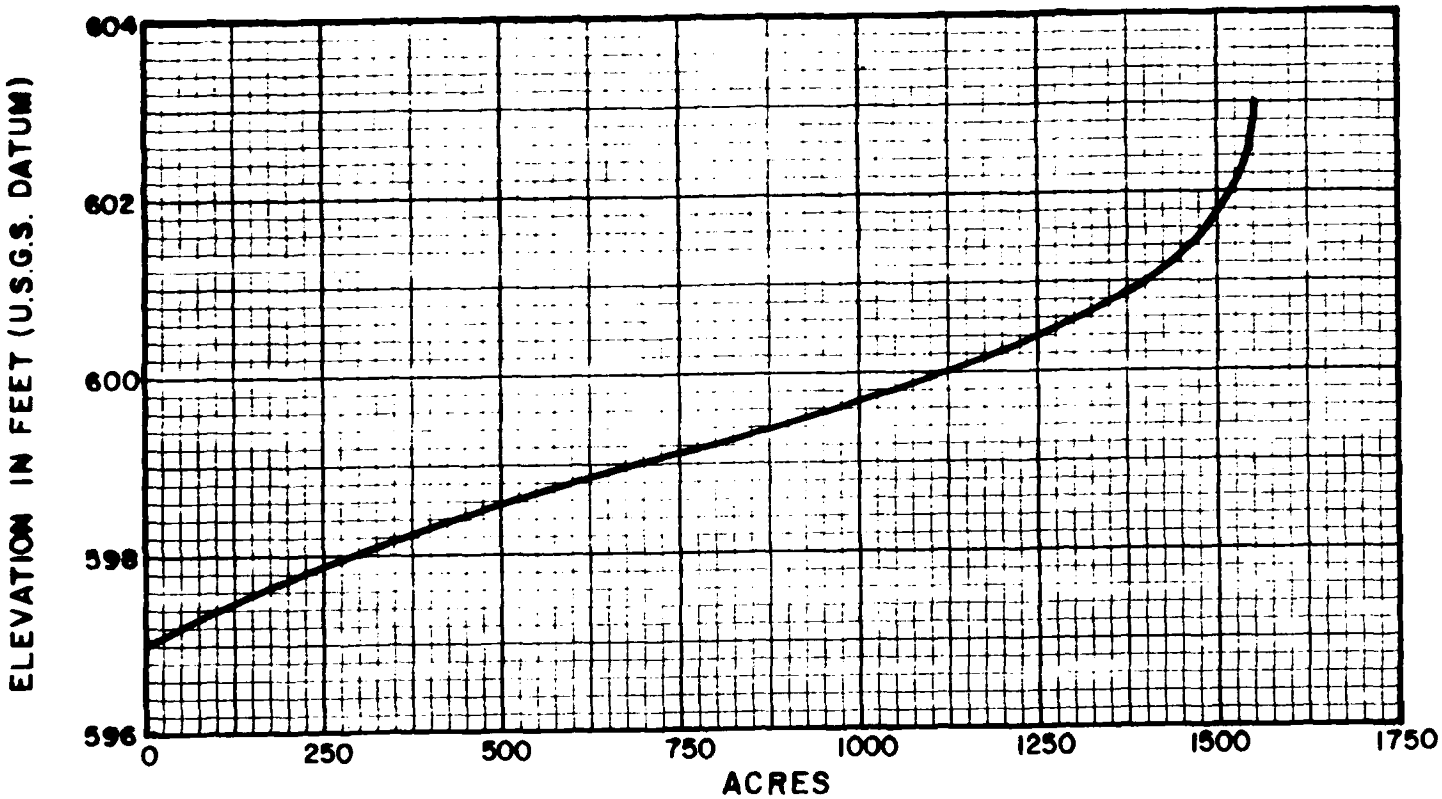

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

TONAWANDA CREEK
INDEX POINT T-8 AT MILE 32.3

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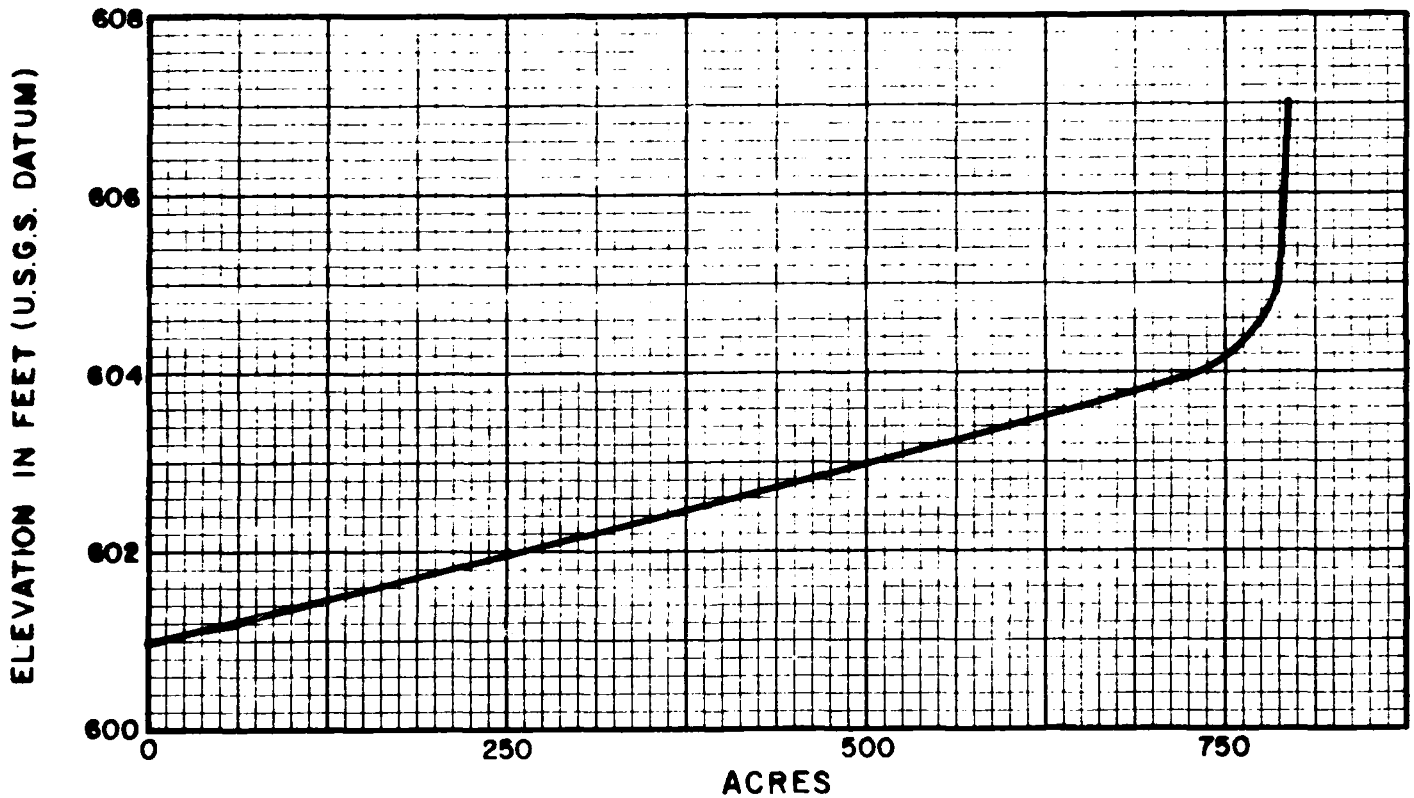

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

TONAWANDA CREEK
INDEX POINT T-9 AT MILE 34.9

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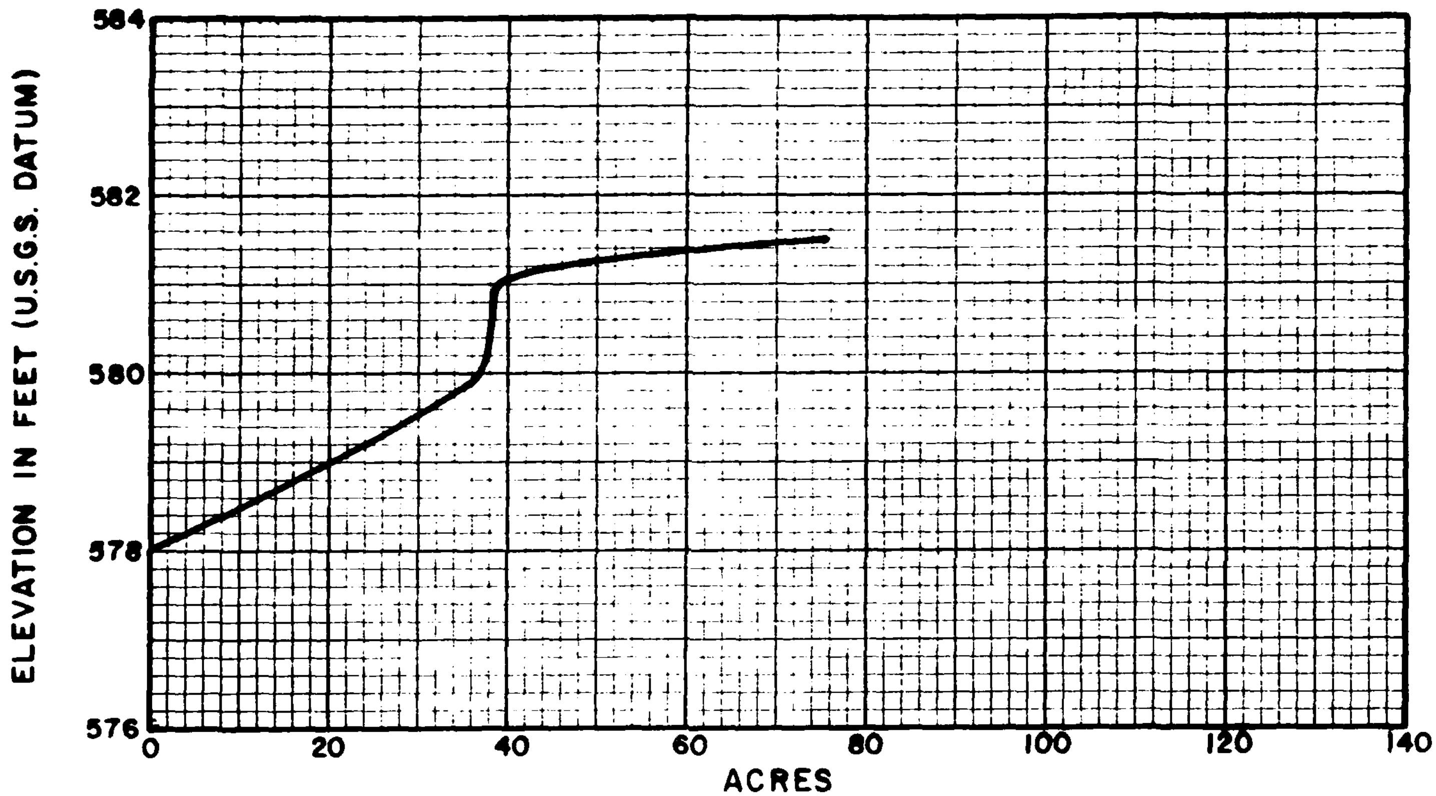
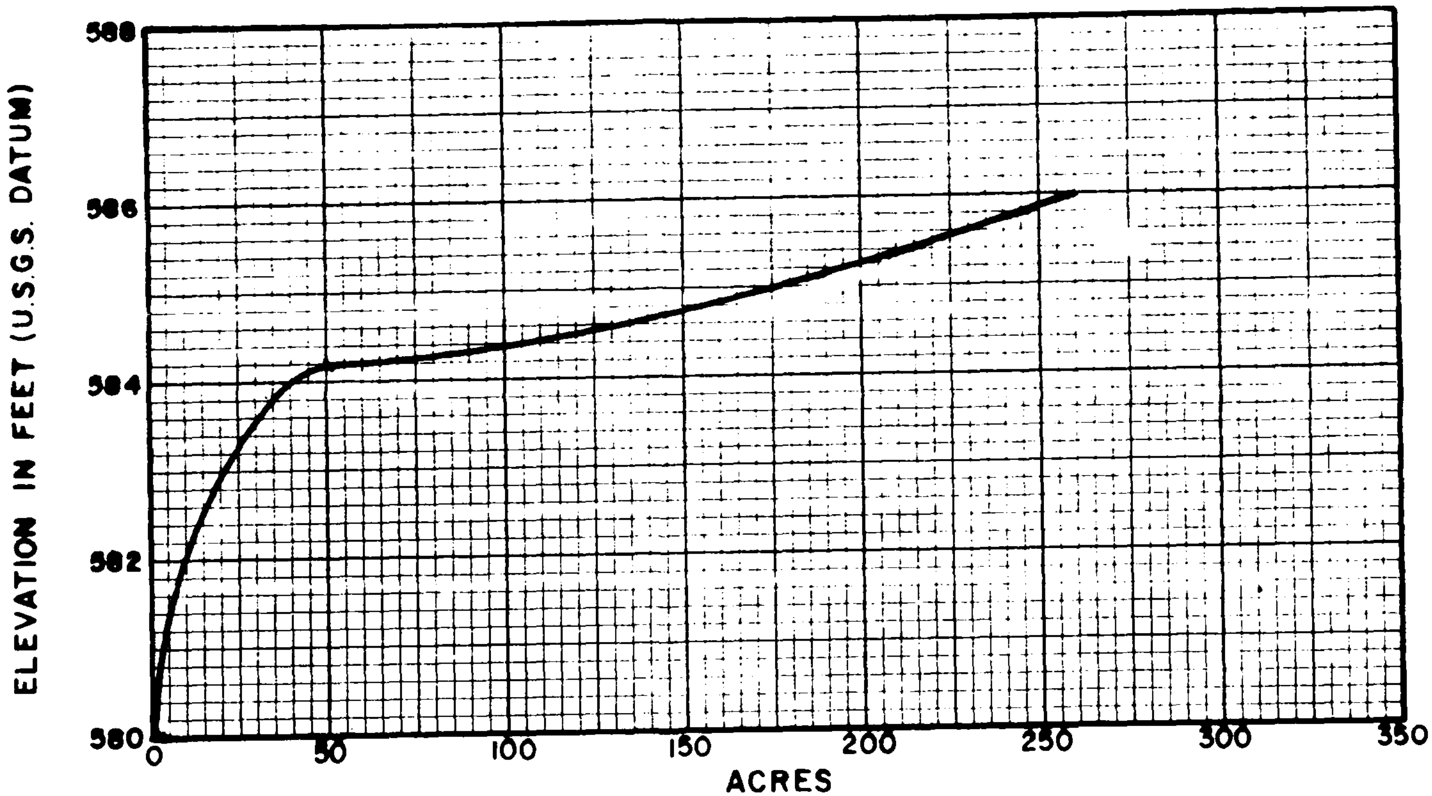


TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

RANSOM AND BLACK CREEK
INDEX POINT RB-1 AT MILE 2.4

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED

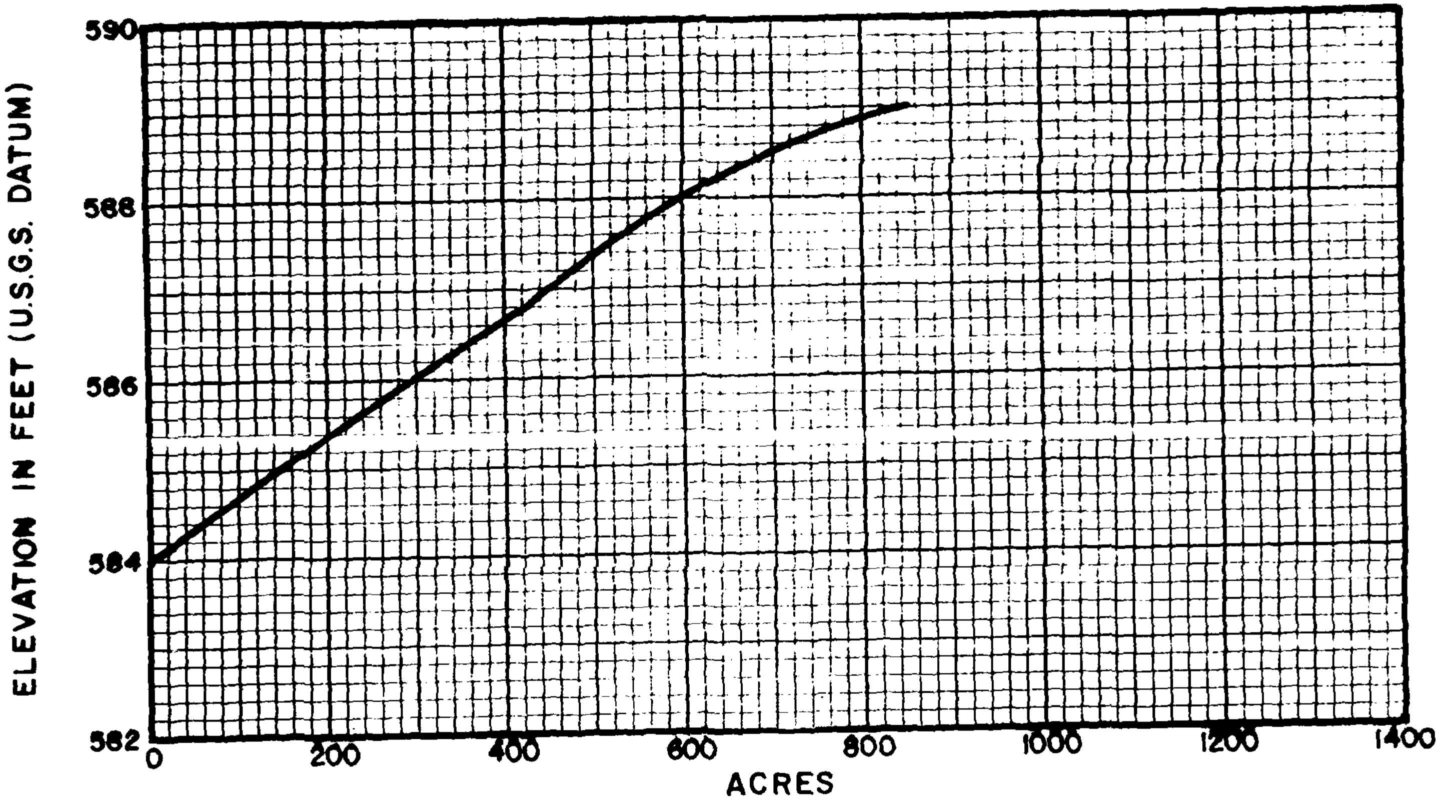


TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

RANSOM AND BLACK CREEK
INDEX POINT RB-2 AT MILE 4.9

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED



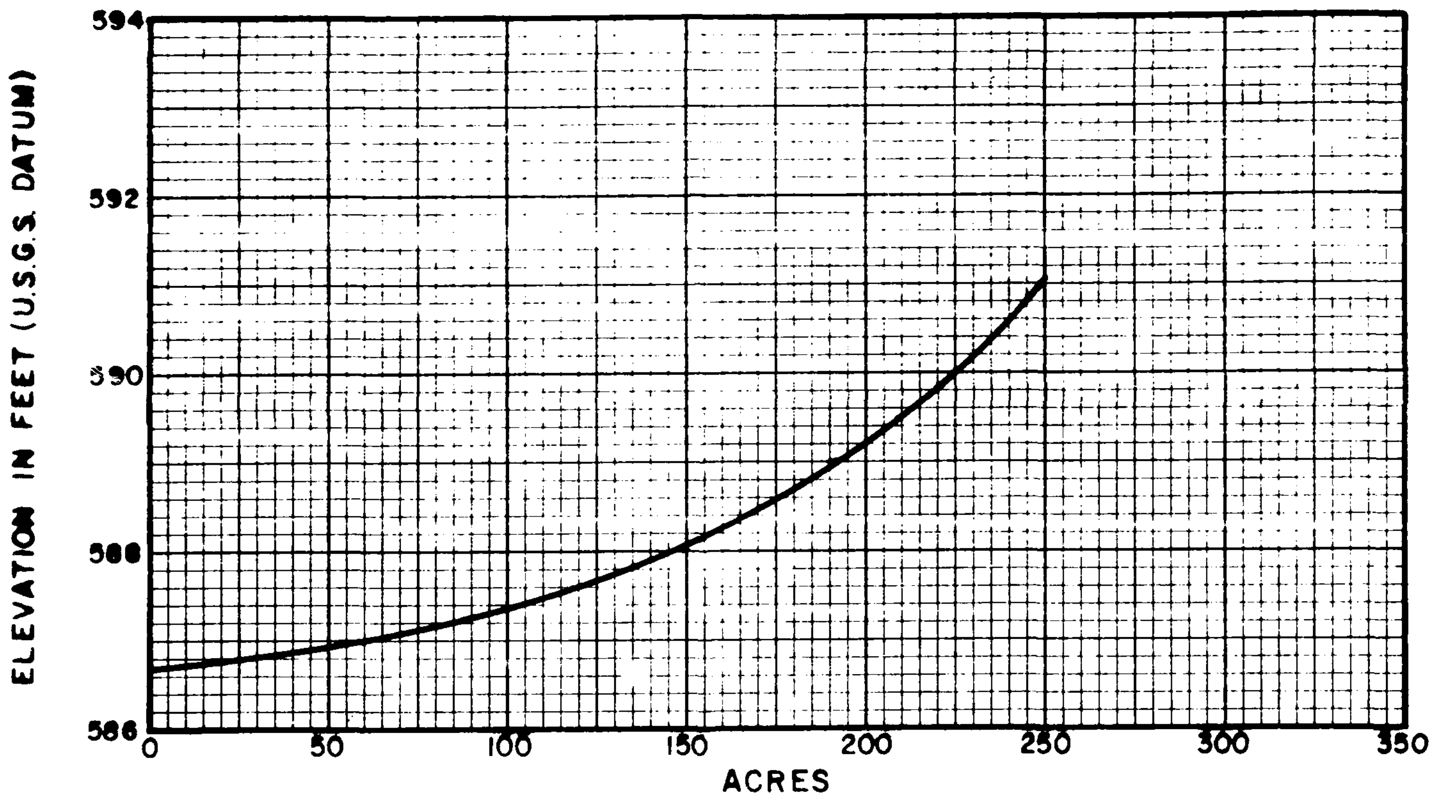
TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

RANSOM AND BLACK CREEK
INDEX POINT RB-3 AT MILE 7.2

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED

PLATE S-10



TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

RANSOM AND BLACK CREEK
INDEX POINT RB-4 AT MILE 8.6

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED

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BUFFALO METROPOLITAN AREA, NEW YORK WATER RESOURCES MANAGEMENT --ETC(U)
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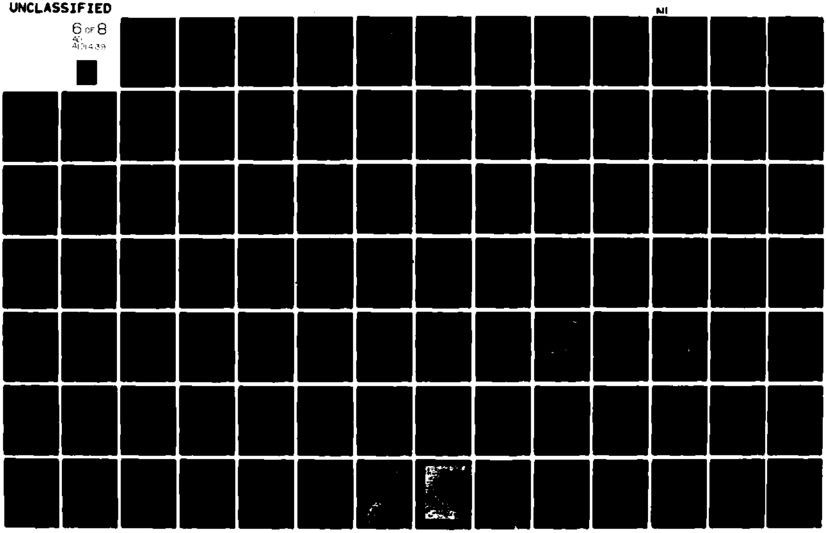
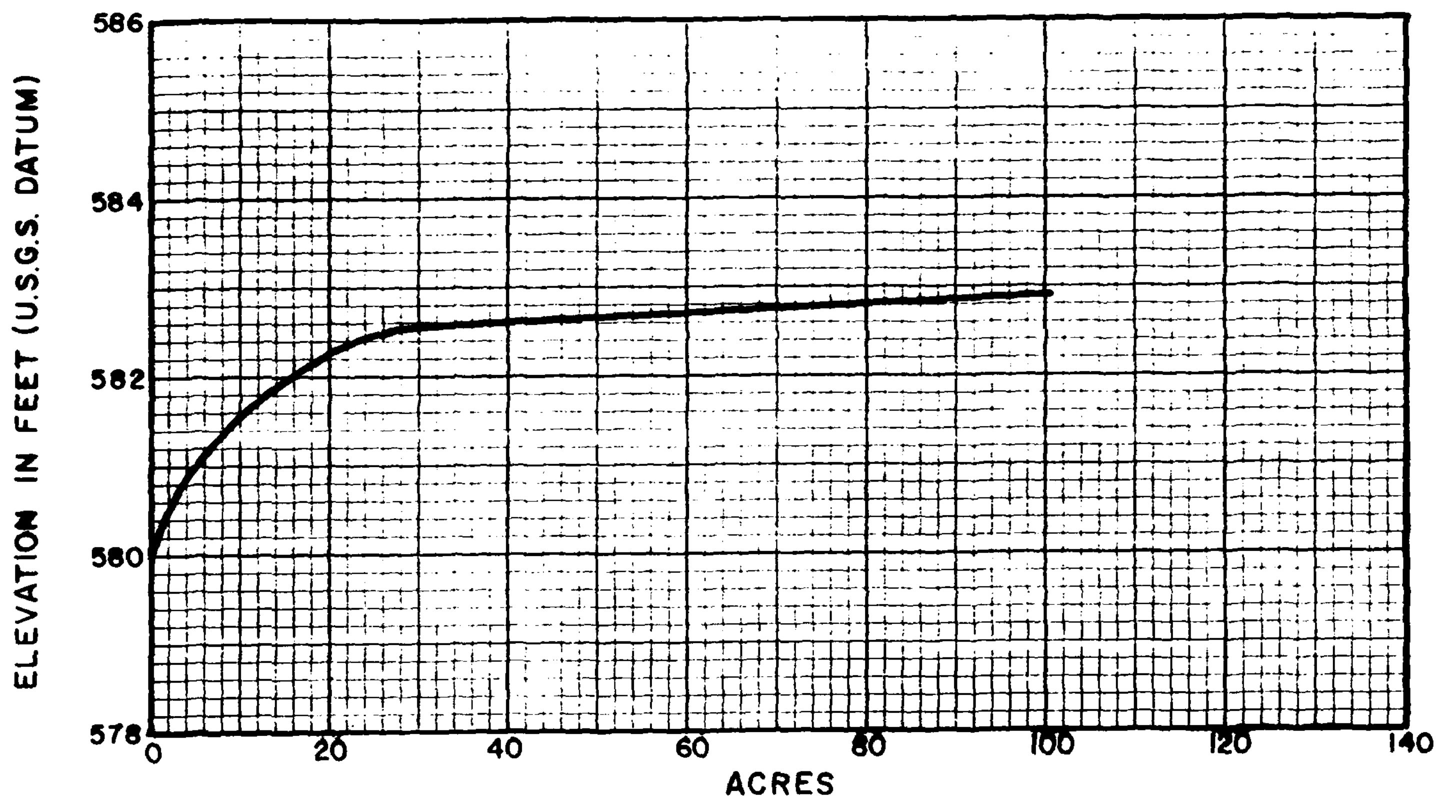




TONAWANDA CREEK WATERSHED, NEW YORK

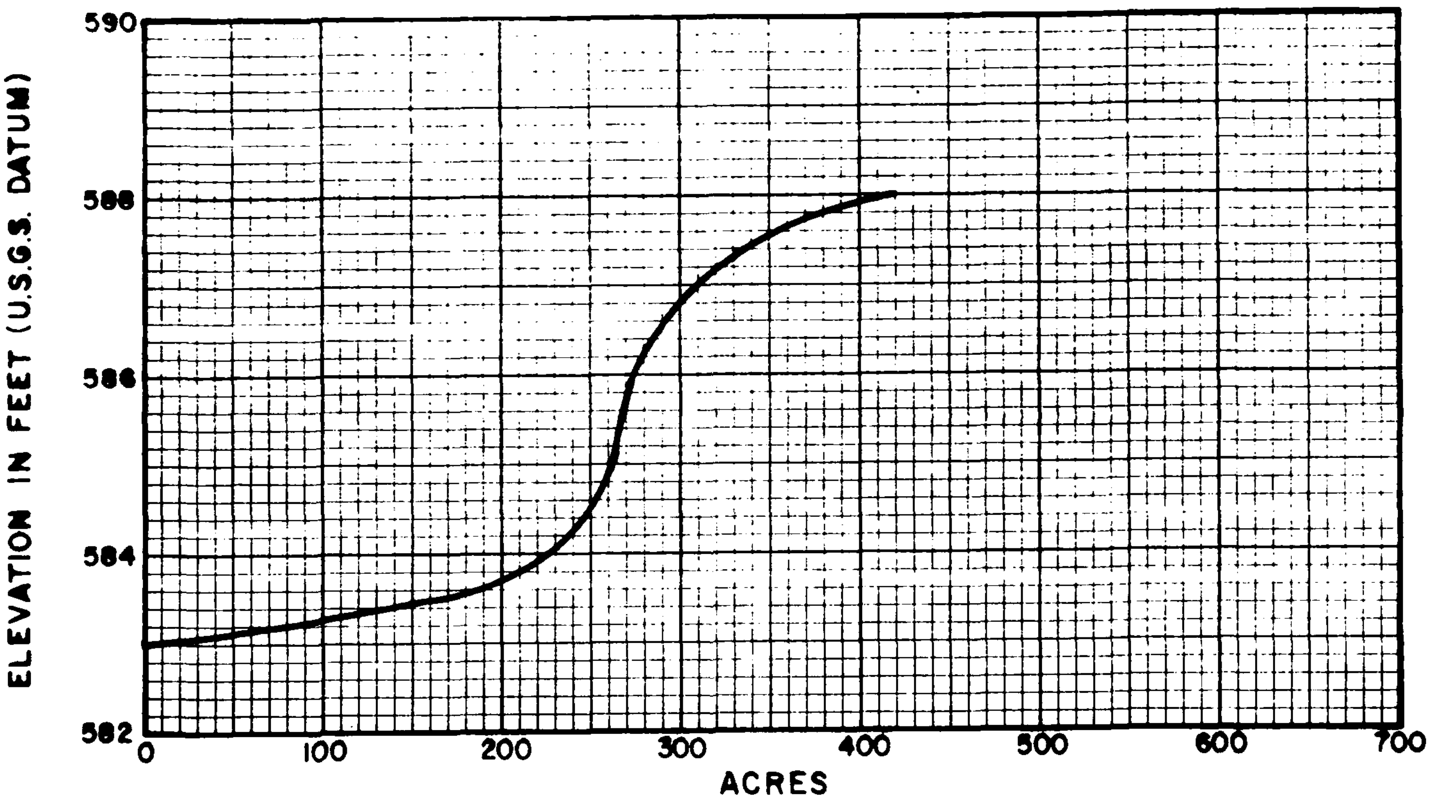
AGRICULTURAL STAGE
AREA CURVE

MUD CREEK

INDEX POINT M-1 AT MILE 1.6

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED

PLATE S-12



TONAWANDA CREEK WATERSHED, NEW YORK

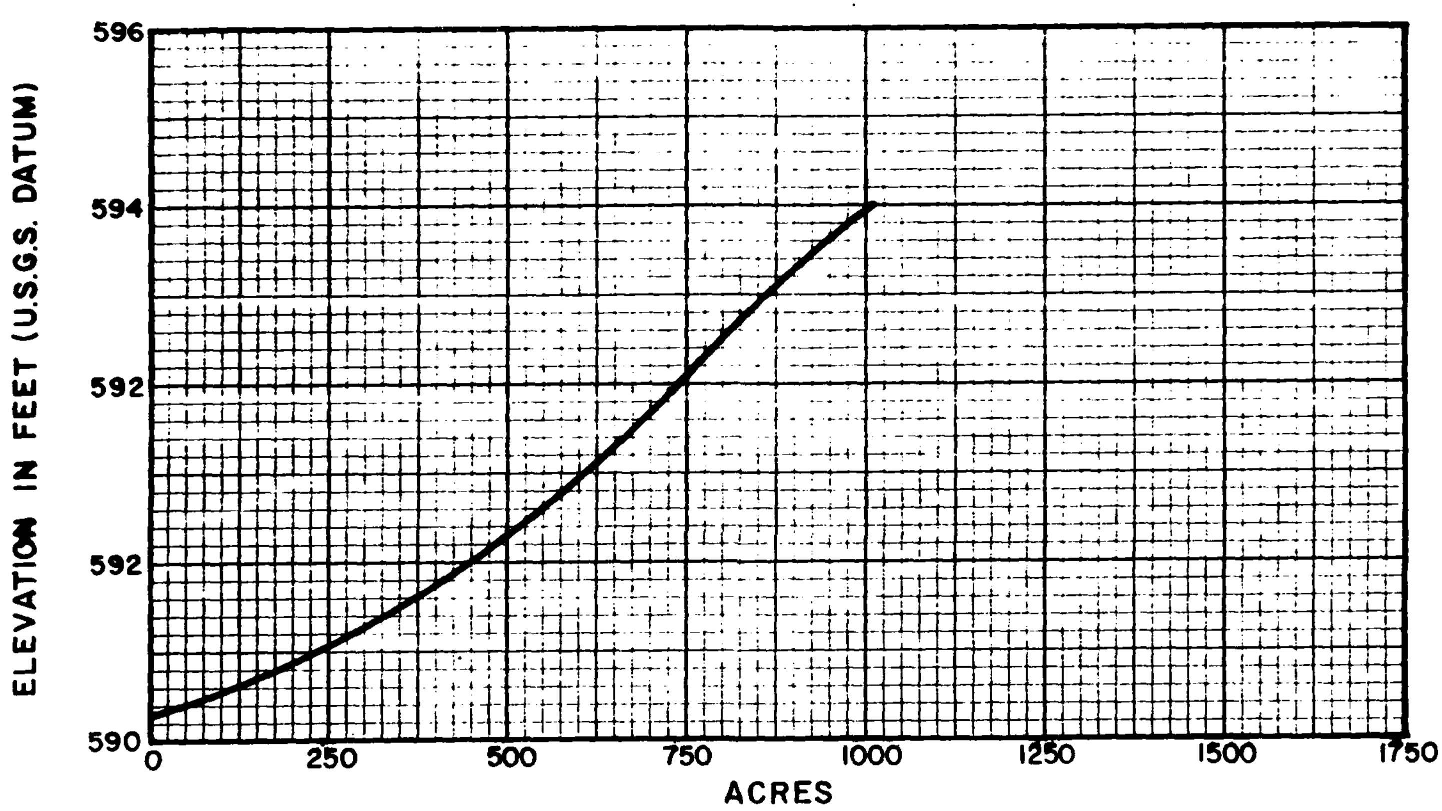
AGRICULTURAL STAGE
AREA CURVE

MUD CREEK

INDEX POINT M-2 AT MILE 3.5

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED

PLATE S-13



TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

MUD CREEK

INDEX POINT M-3 AT MILE 7.0

U.S. ARMY ENGINEER DISTRICT BUFFALO
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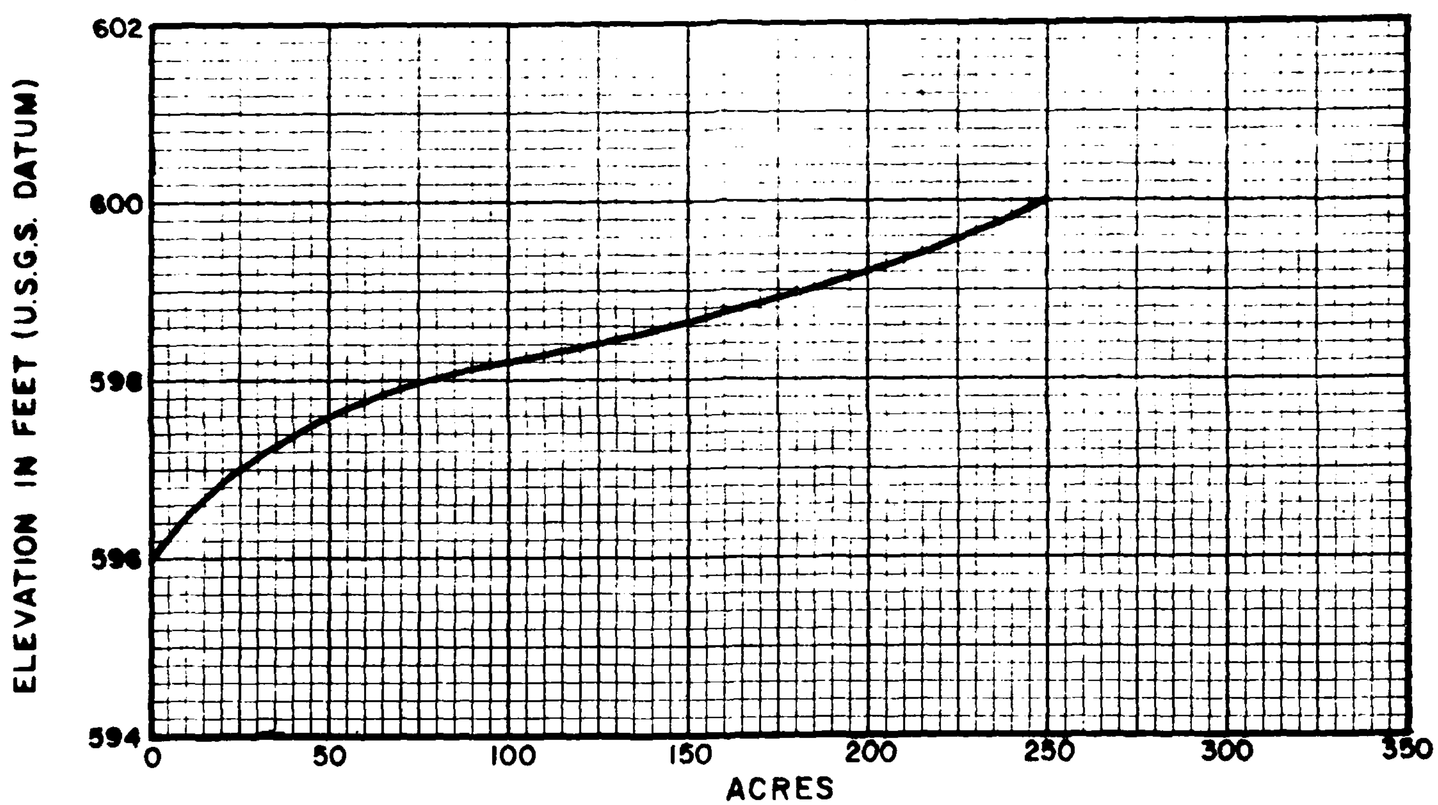

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE AREA CURVE

MUD CREEK

INDEX POINT M-4 AT MILE 10.8

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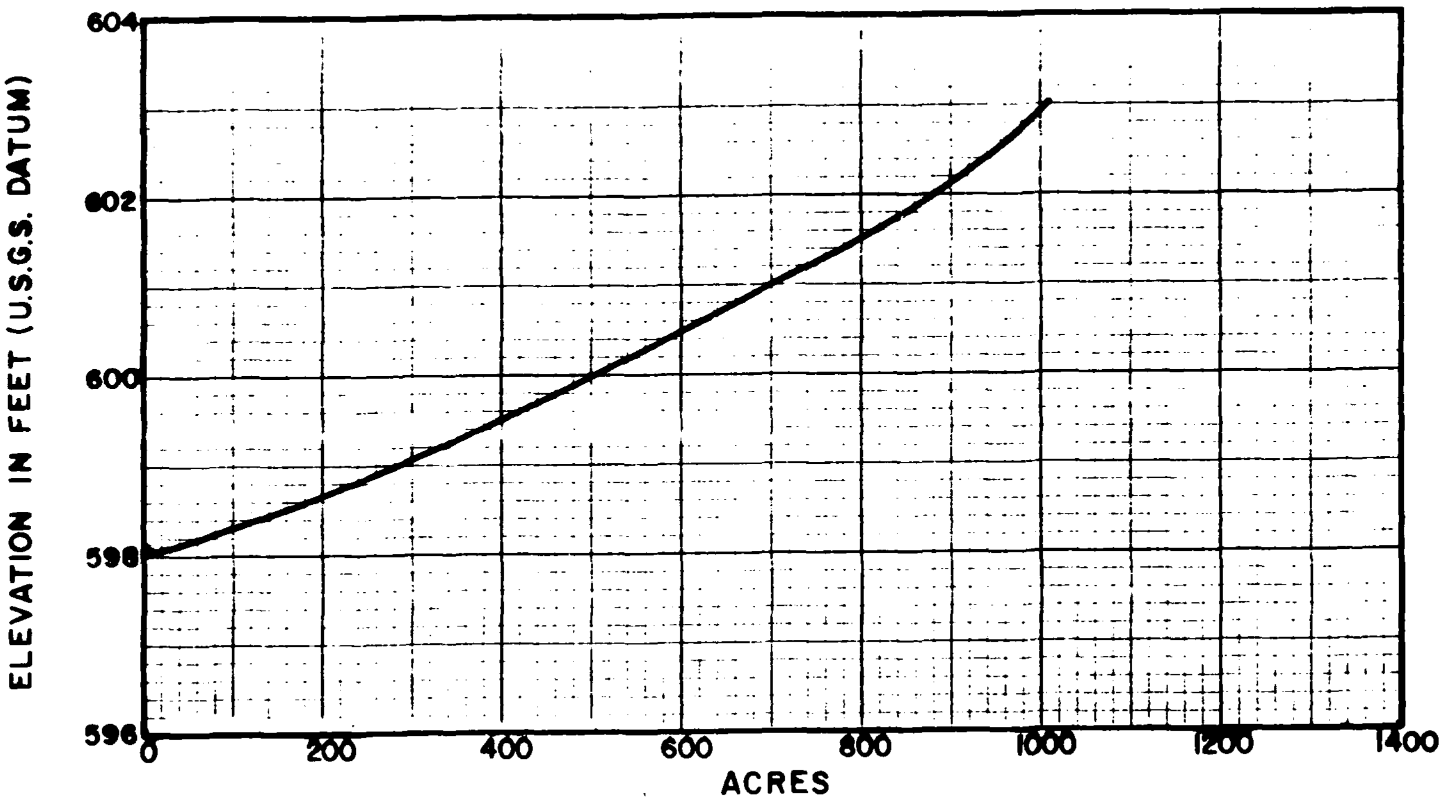

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

MUD CREEK

INDEX POINT M-5 AT MILE 12.5

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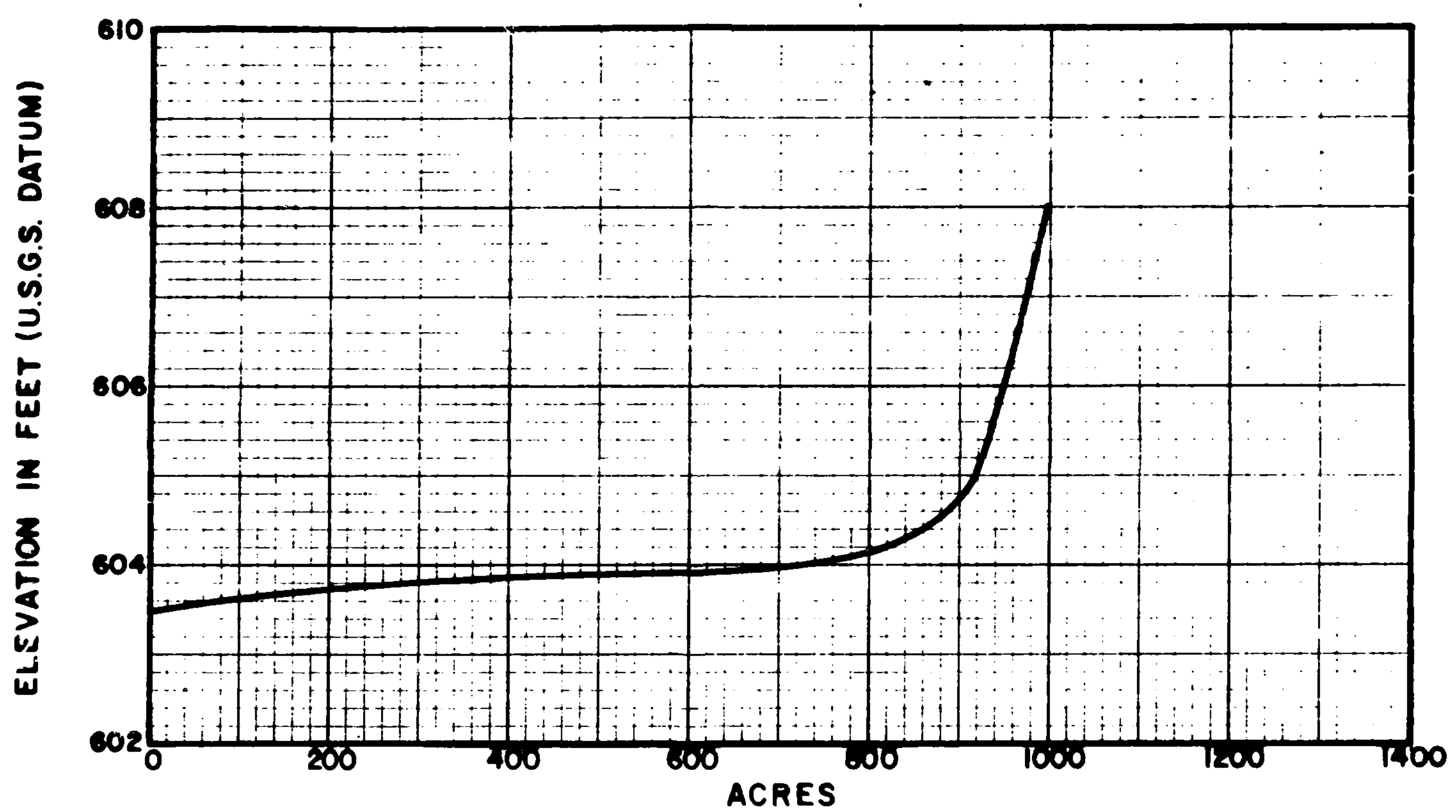

TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

MUD CREEK

INDEX POINT M-6 AT MILE 15.1

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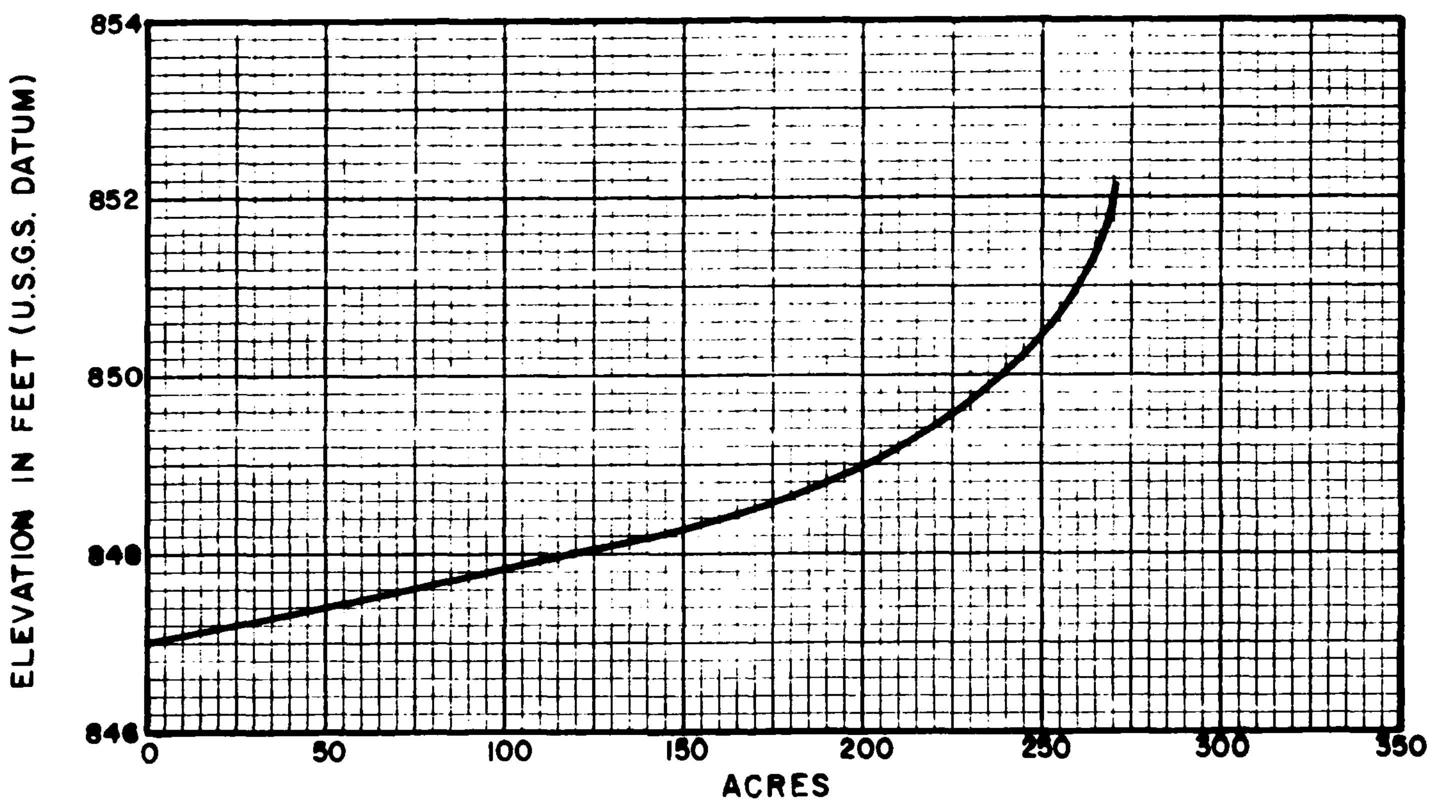
TO ACCOMPANY REPORT DATED



TONAWANDA CREEK WATERSHED, NEW YORK

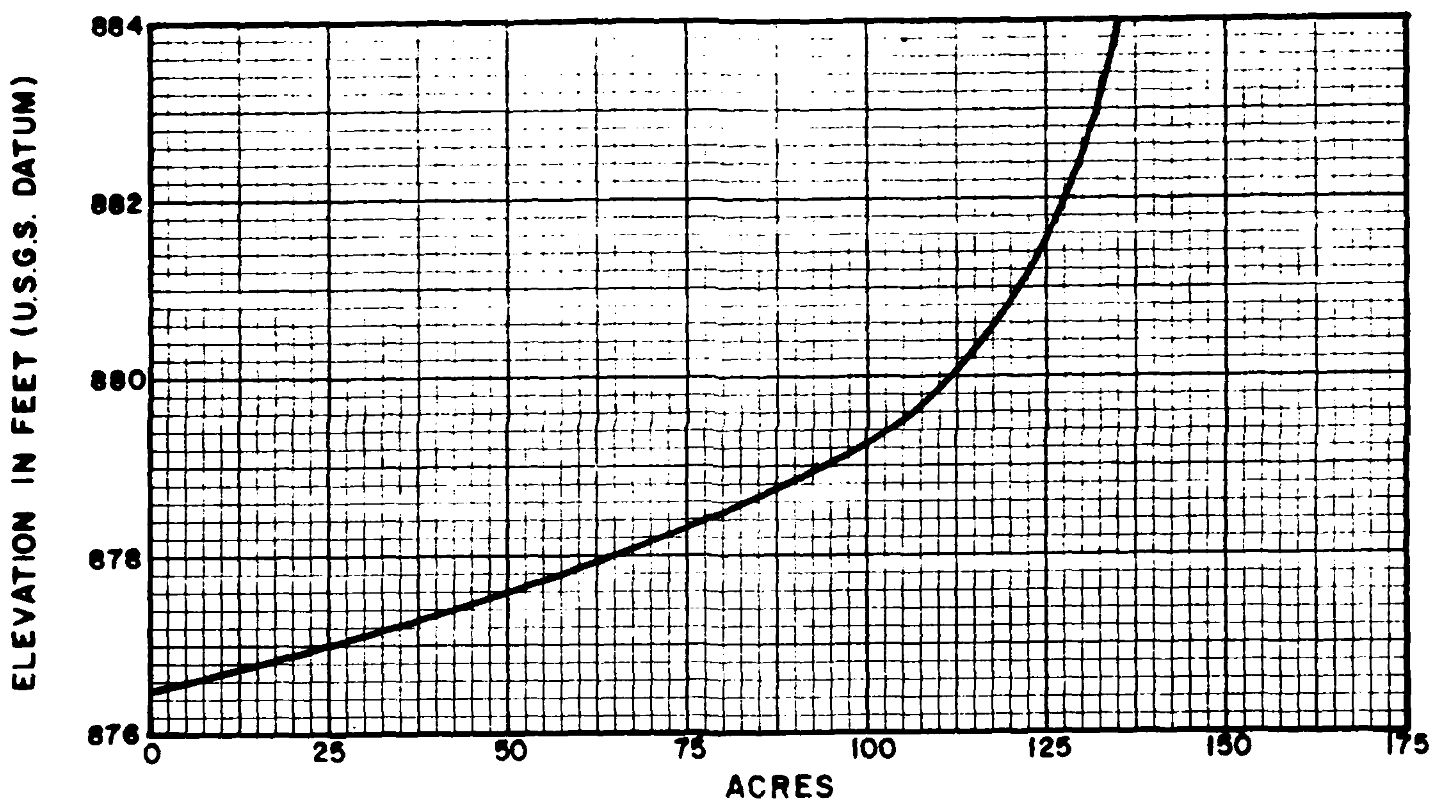
AGRICULTURAL STAGE AREA CURVE

TONAWANDA CREEK

INDEX POINT T-11 AT MILE 52.5

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY REPORT DATED

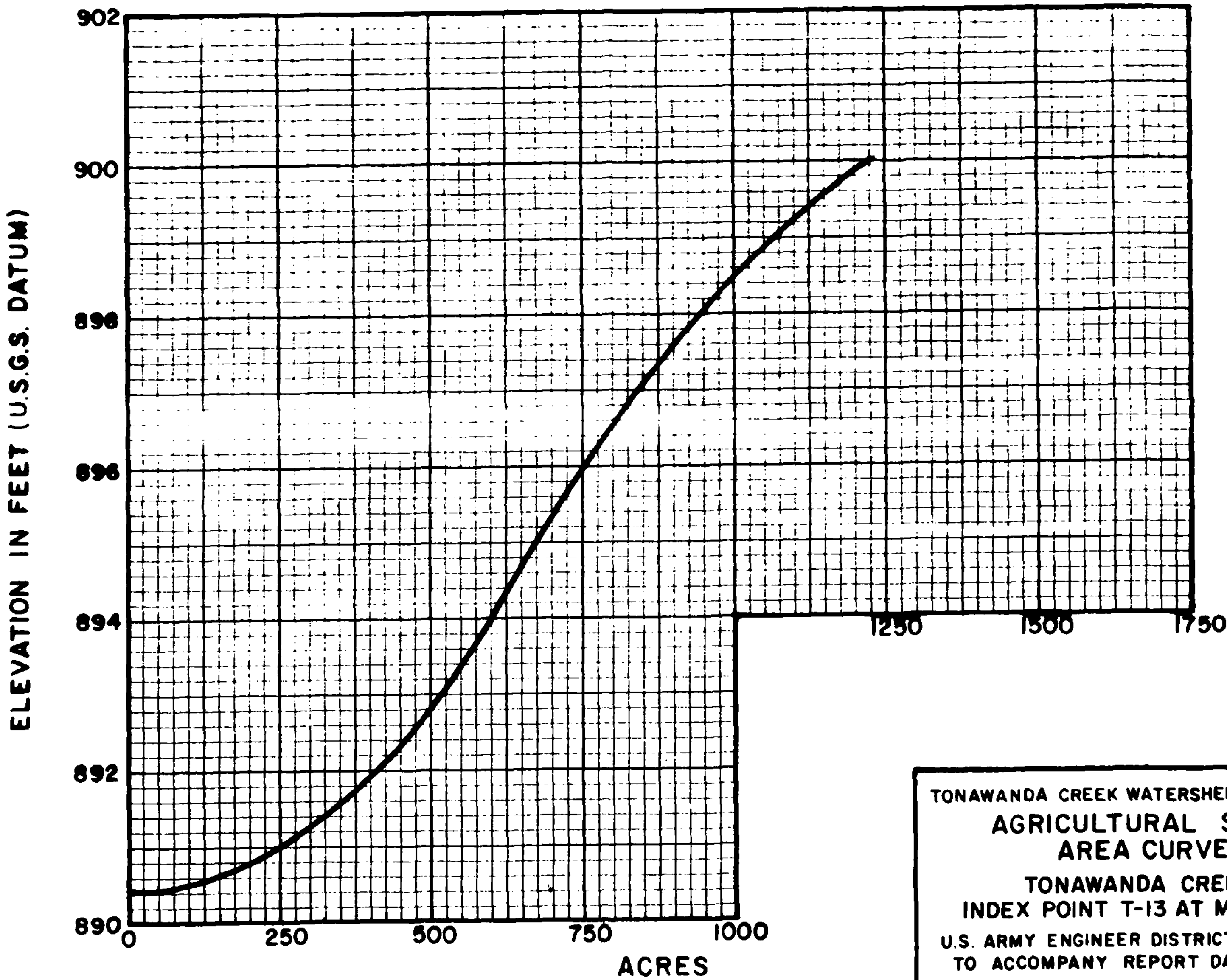


TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

TONAWANDA CREEK
INDEX POINT T-12 AT MILE 60.3

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED



TONAWANDA CREEK WATERSHED, NEW YORK

AGRICULTURAL STAGE
AREA CURVE

TONAWANDA CREEK
INDEX POINT T-13 AT MILE 65.5

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY REPORT DATED

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1980

APPENDIX C

COST ESTIMATES

FOR

ALTERNATIVE PLANS

U. S. Army Corps of Engineers
Buffalo District
Buffalo, New York

FOREWORD

All estimates of costs presented in this appendix are based on December 1975 prices. All estimates of average annual costs are based on 100-year economic life and an interest rate of 6-1/8 percent per annum.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

C1. NON-STRUCTURAL BASE PLAN

1. N.-S. Property Cost.

Item	Estimated Quantity	Unit	Estimated Cost
Purchase of Residential Buildings (fee simple)			
Attica through Alexander	0	each	$ 0
Batavia through Bushville	74	each	2,960,000
Bushville to Hopkins Road	15	each	450,000
Hopkins Road to Sweet Home Road	47	each	1,880,000
Sweet Home Road to Confluence with Ellicott Creek	0	each	0
Ransom and Black Creek	4	each	180,000
Mud Creek	0	each	0
PLAN SUBTOTAL			$5,470,000
Property Acquisition (10% of Property Cost)			547,000
PLAN TOTAL			$6,017,000

2. N.-S. Construction Cost.

Item	Estimated Quantity	Unit	Estimated Cost
Floodproofing (residential)			
Attica through Alexander	20	each	$ 63,100
Batavia through Bushville	1891	each	4,352,500
Bushville to Hopkins Road	85	each	265,400
Hopkins Road to Sweet Home Road	358	each	923,000
Sweet Home to Confluence with Ellicott Creek	1738	each	3,654,000
Ransom and Black Creek	345	each	796,300
Mud Creek	70	each	182,400
PLAN SUBTOTAL			$10,236,700

2. N.-S. Construction Cost. (Cont'd)

Item	Estimated Quantity	Unit	Estimated Cost
Contingencies (25%)			2,559,200
PLAN SUBTOTAL			$12,795,900
Engineering & Design (10%)			1,279,600
Supervision & Admin. (8.5%)			1,087,600
PLAN TOTAL			$15,163,100

3. Summary of First Cost of N.-S. Base Plan.

Item	Amount
Total Property Cost	$ 6,017,000
Total Construction Cost	15,163,100
GRAND TOTAL	$21,180,100

4. Average Annual Cost of N.-S. Base Plan.

Item	Amount
Amortization (.0614)	$ 1,300,500
Operation and Maintenance	115,000
GRAND TOTAL	$ 1,415,500

C2. SIERKS RESERVOIR - LINDEN RESERVOIR

1. S.R.-L.R. Property Cost.

a. Sierks Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	1,100	acre	$ 550,000
Buildings (residential)	26	job	910,000
Farms (plant and equip.)	7	job	700,000
COMPONENT TOTAL			$ 2,160,000

b. Linden Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	1,200	acre	$ 600,000
Buildings (residential)	23	job	805,000
Buildings (public and other)	1	job	100,000
Farms (plant and equip.)	4	job	400,000
COMPONENT TOTAL			$ 1,905,000

c. S.R.-L.R. Plan.

Item	Amount
S.R. Component Total	$2,160,000
L.R. Component Total	1,905,000
PLAN SUBTOTAL	$4,065,000
Property Acquisition (10% of Property Cost)	406,500
PLAN TOTAL	$4,471,500

2. S.R.-L.R. Construction Cost.

a. Sierks Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Care of Water	1	l.s.	$ 158,000	$ 158,000
Clearing and Grubbing	1	l.s.	31,600	31,600
Relocations (Rte. 98)	4.5	mile	526,500	2,369,250
Common Excavation	181,500	c.y.	2.50	453,750
Stripping	33,000	s.y.	0.65	21,450
Line Drilling	20,500	c.y.	5.25	107,625
Rock Excavation	173,000	c.y.	7.40	1,280,200
Compacted Random Fill	697,000	c.y.	2.50	1,742,500
Compacted Filter and Transition Material	24,000	c.y.	10.00	240,000
Rock Fill	34,000	c.y.	26.30	894,200
Unreinforced Concrete	94,000	c.y.	100.00	9,400,000
Reinforced Concrete	16,300	c.y.	125.00	2,037,500
Tainter Gates	4	each	131,625	526,500
Slide Gates	10	each	63,180	631,800
Service Bridge	1	each	94,770	94,770
Miscellaneous Items	1	l.s.	$1,474,200	$ 1,474,200
Mobilization and Demobilization	1	l.s.	1,092,000	1,092,000
COMPONENT TOTAL				$22,939,345

b. Linden Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Relocation (cemetery)	1	l.s.	36,800	$ 36,800
Relocation (county roads)	1	mile	579,000	579,100
Relocations (phone and power)	1	mile	7,400	7,400
Clearing and Grubbing	103	acre	2,000	206,000
Compacted Impervious Fill	350,000	c.y.	4.00	1,400,000
Principal Spillway	1	l.s.	4,393,000	4,393,000
Mobilization and Demobilization	1	l.s.	331,000	331,000
COMPONENT TOTAL				$6,953,300

2. S.R.-L.R. Construction Cost. (Cont'd)

c. S.R.-L.R. Plan.

Item	Amount
S.R. Component Total	$22,939,345
L.R. Component Total	6,953,300
PLAN SUBTOTAL	$29,892,600
Contingencies (15%)	4,483,900
PLAN SUBTOTAL	$34,376,500
Engineering & Design (10%)	3,437,700
Supervision & Administration (7.5%)	2,578,200
Interest During Construction (6-1/8%)	2,105,600
PLAN TOTAL	$42,498,000

3. Summary of First Cost for S.R.-L.R. Plan.

Item	Amount
Total Property Cost	$ 4,471,500
Total Construction Cost	42,498,000
GRAND TOTAL	$46,969,500

4. Average Annual Cost for S.R.-L.R. Plan.

Item	Amount
Amortization (.0614)	$ 2,883,900
Operation and Maintenance	100,000
GRAND TOTAL	$ 2,983,900

C3. SIERKS RESERVOIR - ALABAMA RESERVOIR COMPOUND

1. S.R.-A.R.C. Property Cost.

a. Sierks Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	1,100	acre	$ 550,000
Buildings (residential)	26	job	910,000
Farms (plant and equipment)	7	job	700,000
COMPONENT TOTAL			$2,160,000

b. Alabama Reservoir Compound.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	45	acre	$ 22,500
Land (easements)	5,500	acre	550,000
Buildings (residential)	9	job	315,000
Buildings (public and other)	1	job	50,000
COMPONENT TOTAL			$ 937,500

c. S.R.-A.R.C. Plan.

Item	Amount
S.R. Component Total	$2,160,000
A.R.C. Component Total	937,500
PLAN SUBTOTAL	$3,097,500
Property Acquisition (10% of Property Cost)	309,800
PLAN TOTAL	$3,407,300

2. S.R.-A.R.C. Construction Cost.

a. Sierks Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Care of Water	1	l.s.	$ 158,000	$ 158,000
Clearing and Grubbing	1	l.s.	31,600	31,600
Relocations (Rte. 98)	4.5	mile	526,500	2,369,250
Common Excavation	181,500	c.y.	2.50	453,750
Stripping	33,000	s.y.	0.65	21,450
Line Drilling	20,500	c.y.	5.25	107,625
Rock Excavation	173,000	c.y.	7.40	1,280,200
Compacted Random Fill	697,000	c.y.	2.50	1,742,500
Compacted Filter and Transition Material	24,000	c.y.	10.00	240,000
Rock Fill	34,000	c.y.	26.30	894,200
Unreinforced Concrete	94,000	c.y.	100.00	9,400,000
Reinforced Concrete	16,300	c.y.	125.00	2,037,500
Tainter Gates	4	each	131,625	526,500
Slide Gates	10	each	63,180	631,800
Service Bridge	1	each	94,770	94,770
Miscellaneous Items	1	l.s.	1,474,200	1,474,200
Mobilization and Demobilization	1	l.s	1,092,000	1,092,000
COMPONENT TOTAL				$22,939,345

b. Alabama Reservoir Compound.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Relocations (highways)		l.s.	$ 613,000	$ 613,000
Clearing and Grubbing	107	l.s.	2,000	214,000
Stripping	256,500	s.y.	0.65	166,725
Compacted Random Fill	2,143,000	c.y.	2.50	5,357,500
Reinforced Concrete for Inlet and Principal Spillways Structure		l.s.	1,118,900	1,118,900
Seeding, Fertilizing and Mulching	108	acre	1,100	118,800
Common Excavation	812,000	c.y.	2.50	2,030,000
Mobilization and Demobilization		l.s.	481,000	481,000
COMPONENT TOTAL				$10,099,925

c. S.R.-A.R.C. Plan.

Item	Amount
S.R. Component Total	$22,939,300
A.R.C. Component Total	10,099,900
PLAN SUBTOTAL	$33,039,200
Contingencies (15%)	4,955,900
PLAN SUBTOTAL	$37,995,100
Engineering & Design (10%)	3,799,500
Supervision & Administration (7.5%)	2,849,600
Interest During Construction (6-1/8%)	2,327,200
PLAN TOTAL	$46,971,400

3. Summary of First Cost for S.R.-A.R.C. Plan.

Item	Amount
Total Property Cost	$ 3,407,300
Total Construction Cost	46,971,400
GRAND TOTAL	$ 50,378,700

4. Average Annual Cost for S.R.-A.R.C. Plan.

Item	Amount
Amortization (.0614)	$ 3,093,300
Operation and Maintenance	100,000
GRAND TOTAL	$ 3,193,300

C4. ALEXANDER RESERVOIR

1. A.R. Property Cost.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	945	acre	$ 472,500
Building (residential)	8	job	280,000
PLAN SUBTOTAL			$ 752,500
Property Aquisition (10% of Property Cost)			75,300
PLAN TOTAL			$ 827,800

2. A.R. Construction Cost.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Earth Dam				
Clearing & Grubbing	25	acre	$2,000.00	$ 50,000
Stripping	106,000	s.y.	0.65	68,900
Common Excavation	104,000	c.y.	2.50	260,000
Compacted Random Fill	342,700	c.y.	2.50	856,750
Compacted Impervious Fill	143,200	c.y.	4.00	572,800
Compacted Filter and Transition Material	80,500	c.y.	10.00	805,000
Seeding, Fertilizing and Mulching	117,200	s.y.	0.23	26,956
Access Roadway (top of dam)	11,200	s.y.	7.85	87,920
Access Roadway (guard rail)	11,000	l.f.	7.50	82,500
SUBTOTAL				$2,810,826
Principal Outlet Works				
Common Excavation	30,000	c.y.	$ 2.50	$ 75,000
Compacted Select Fill	9,825	c.y.	4.00	39,300
Concrete (structural)	7,514	c.y.	150.00	1,127,100

2. A.R. Construction Cost. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Concrete (reinforced)	381	c.y.	125.00	47,625
Concrete (unreinforced)	3,868	c.y.	100.00	386,800
Tainter Gates & Anchorage	365,387	lbs.	1.50	548,080
Tainter Gate Machinery	5	ea.	30,000.00	150,000
Tainter Gate Housing	6	ea.	7,200.00	43,200
Stop Logs (One Set)		l.s.		95,000
Steel Sheet Piling	5,935	s.f.	8.00	47,480
Electrical Facilities		l.s.		185,000
Service Bridge	5	ea.	4,350.00	21,750
SUBTOTAL				$2,766,335
Channels				
Common Excavation	35,900	c.y.	2.50	89,750
24" Riprap with Bedding	5,500	s.y.	35.30	194,150
SUBTOTAL				$ 283,900
Railroad Floodgate				
Common Excavation	3,260	c.y.	2.50	8,150
Compacted Select Fill	1,430	c.y.	4.00	5,720
Concrete (reinforced)	1,920	c.y.	125.00	240,000
Floodgate & Guides	25,650	lbs.	1.50	38,475
Floodgate Machinery		l.s.		20,000
Machinery Housing		l.s.		10,000
Steel Sheet Piling	3,290	s.f.	8.00	26,320
Track Relocation				6,000
Electrical Facilities		l.s.		50,000
Service Bridge		l.s.		2,500
SUBTOTAL				$ 407,165
Highway Relocation	2,700	s.y.	7.85	21,165
Bridge Relocation		l.s.		34,400
Care of Water		l.s.		100,000
Mobilization and Preparatory Work		l.s.		325,000
PLAN SUBTOTAL				$6,748,821
Contingencies (20%)				1,349,800
PLAN SUBTOTAL				$8,098,600

2. <u>A.R. Construction Cost</u>. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Engineering & Design (10%)				809,900
Supervision & Administration (9.5%)				769,400
PLAN TOTAL				$9,677,900

3. <u>Summary of First Cost for A.R. Plan</u>.

Item	Amount
Total Property Cost	$ 827,800
Total Construction Cost	9,677,900
GRAND TOTAL	$10,505,700

4. <u>Average Annual Cost for A.R. Plan</u>.

Item	Amount
Amortization (.0614)	$ 645,600
Operation and Maintenance	50,000
GRAND TOTAL	$ 695,000

C5. BATAVIA RESERVOIR COMPOUND

1. B.R.C. Property Cost.

a. Upper Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	945	acre	$ 472,500
Buildings (residential)	8	job	280,000
COMPONENT TOTAL			$ 752,500

b. Lower Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
Land (easements for reservoir)	3,900	acre	$ 390,000
Land (easements for emergency spillway)	1,730	acre	173,000
Buildings (residential)	32	job	1,120,000
Farms (plant and equip.)	3	job	300,000
Sand and Gravel Operations (plant and equipment)	1	job	100,000
COMPONENT TOTAL			$2,083,000

c. B.R.C. Plan.

Item	Amount
U.R. Component Total	$ 752,500
L.R. Component Total	2,083,000
COMPONENT TOTAL	$2,835,500
Property Acquisition (10% of Property Cost)	283,600
PLAN TOTAL	$3,119,100

2. B.R.C. Construction Cost.

a. Upper Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Earth Dam and Emergency Spillway				
Clearing & Grubbing	25	acre	$2,000.00	$ 50,000
Stripping	83,300	s.y.	.65	54,145
Common Excavation	94,800	c.y.	2.50	237,000
Compacted Random Fill	156,500	c.y.	2.50	391,250
Compacted Impervious Fill	118,200	c.y.	4.00	472,800
Compacted Filter and Transition Material	87,500	c.y.	10.00	875,000
18" Riprap	91,100	s.y.	17.00	1,548,700
Seeding, Fertilizing, Mulching	57,300	s.y.	.23	13,179
Access Roadway (top of dam)	11,560	s.y.	7.85	90,746
Access Roadway (guard rail)	10,000	l.f.	7.50	75,000
SUBTOTAL				$3,807,820
Principal Outlet Works				
Common Excavation	8,625	c.y.	2.50	$ 21,562
Compacted Select Fill	1,175	c.y.	4.00	4,700
Concrete (reinforced)	1,839	c.y.	125.00	229,875
Fixed Wheel Sluice Gates and Misc. Fabrications	45,000	lbs.	$ 1.50	$ 68,250
Sluice Gate Electric Lift	5	ea.	5,000.00	25,000
Stop Logs (one set)		l.s.		10,000
Steel Sheet Piling	2,780	s.f.	8.00	22,240
24" Riprap with Bedding	1,105	s.y.	35.30	39,007
Electrical Facilities		l.s.		85,000
Common Excavation (outlet channel)	19,800	c.y.	2.50	49,500
SUBTOTAL				$555,134

2. <u>B.R.C. Construction Cost</u>. (Cont'd)

a. <u>Upper Reservoir</u> (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
<u>Railroad Floodgate</u>				
Common Excavation	2,370	c.y.	2.50	5,925
Compacted Select Fill	1,023	c.y.	4.00	4,092
Concrete (reinforced)	1,304	c.y.	125.00	163,000
Floodgate & Guides	19,000	lbs.	1.50	28,500
Floodgate Machinery		l.s.		2[illegible],000
Machinery Housing		l.s.		10,000
Steel Sheet Piling	3,290	s.f.	8.00	26,320
Track Relocation		l.s.		6,000
Electrical Facilities		l.s.		50,000
Service Bridge		l.s.		2,500
SUBTOTAL				$ 316,337
Highway Relocation	2,700	s.y.	7.85	21,195
Bridge Relocation		l.s.		34,400
Care of Water		l.s.		100,000
Mobilization and Preparatory Work		l.s.		250,000
COMPONENT TOTAL				$5,084,886

b. <u>Lower Reservoir</u>.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
<u>Earth Dam</u>				
Clearing & Grubbing	29	acre	$2,000.00	$ 58,000
Stripping	187,000	s.y.	.65	121,550
Common Excavation	219,000	c.y.	2.50	547,500
Compacted Random Fill	350,000	c.y.	2.50	875,000
Compacted Impervious Fill	284,000	c.y.	4.00	1,136,000
Compacted Filter and Transition Material	160,000	c.y.	10.00	1,600,000

2. B.R.C. Construction Cost. (Cont'd)

b. Lower Reservoir. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Seeding, Fertilizing and Mulching	197,000	s.y.	$ 0.23	$ 45,310
Access Roadway (top of dam)	13,400	s.y.	7.85	105,190
Access Roadway (guard rail)	12,000	l.f.	7.50	90,000
SUBTOTAL				$4,578,550
Emergency Spillway				
Common Excavation	195,000	c.y.	2.50	487,500
Compacted Random Fill	10,000	c.y.	2.50	25,000
Seeding, Fertilizing and Mulching	224,000	s.y.	0.23	51,520
Highway Relocation	3,320	l.f.	50.00	166,000
SUBTOTAL				$ 730,020
Ellicott St. Culvert				
Common Excavation	2,650	c.y.	2.50	6,625
Concrete (reinforced)	30	c.y.	125.00	3,750
Concrete Pipe (72" diam.)	97	l.f.	140.00	13,580
Sluice Gate		l.s.		17,000
SUBTOTAL				$ 40,955
Principal Outlet Works				
Common Excavation	2,900	c.y.	2.50	7,250
Compacted Select Fill	860	c.y.	4.00	3,440
Concrete (reinforced)	1,391	c.y.	125.00	173,875
Fixed Wheel Sluice Gates and Misc. Fabrications	37,400	lbs.	1.50	56,100
Sluice Gate Electric Lift	4	ea.	5,000.00	20,000
Stop Logs (one set)		l.s.		10,000
Steel Sheet Piling	4,400	s.f.	8.00	35,200

2. B.R.C. Construction Cost. (Cont'd)

b. Lower Reservoir. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
24" Riprap with Bedding	1,222	s.y.	35.30	43,136
Electrical Facilities		l.s.		50,000
SUBTOTAL				$ 399,001
Railroad Floodgate				
Common Excavation	2,370	c.y.	2.50	5,925
Compacted Select Fill	1,023	c.y.	4.00	4,092
Concrete (reinforced)	1,304	c.y.	125.00	163,000
Floodgate & Guides	19,000	lbs.	1.50	28,500
Floodgate Machinery		l.s.		20,000
Machinery Housing		l.s.		10,000
Steel Sheet Piling	3,290	s.f.	8.00	26,320
Track Relocation		l.s.		6,000
Electrical Facilities		l.s.		84,000
Service Bridge		l.s.		2,500
SUBTOTAL				$ 350,337
Care of Water		l.s.		200,000
Mobilization and Preparatory Work		l.s.		325,000
Clearing and Snagging	8	mile	13,500.00	108,000
COMPONENT TOTAL	8	mile	13,500.00	$6,731,863

c. B.R.C. Plan.

Item	Amount
U.R. Component Total	$ 5,084,900
L.R. Component Total	6,731,900
PLAN SUBTOTAL	$11,816,800

2. B.R.C. Construction Cost. (Cont'd)

c. B.R.C. Plan (Cont'd)

Item	Amount
Contingencies (15%)	$ 1,772,500
PLAN SUBTOTAL	$13,589,300
Engineering and Design (10%)	1,358,900
Supervision and Administration (8.5%)	1,155,100
Interest During Construction (6-1/8%)	832,300
PLAN TOTAL	$16,935,600

3. Summary of First Cost for B.R.C. Plan.

Item	Amount
Total Property Cost	$ 3,119,100
Total Construction Cost	16,935,600
GRAND TOTAL	$20,054,700

4. Average Annual Cost for B.R.C. Plan.

Item	Amount
Amortization (.0614)	$ 1,232,000
Operation and Maintenance	100,000
GRAND TOTAL	$ 1,332,000

C6. BATAVIA RESERVOIR

1. B.R. Property Cost.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	6,460	acres	$3,230,000
Land (easements)	1,730	acres	173,000
Land (extinguishment of mineral rights)	100	acres	350,000
Buildings (residential)	82	job	2,870,000
Structures (radio station)	1	job	50,000
Structures (pipeline sta.)	1	job	100,000
Farms (Plant & Equipment)	7	job	700,000
Sand and Gravel Operations (plant equipment)	4	job	400,000
Relocations			
Power Line (9,000 ft.)	1	job	735,300
Settling Lagoon Compound	1	job	50,000
Private Recreation Facility	1	job	40,000
Elevation of 3 miles of County Roads (includes 24 ft. culvert)	1	job	100,000
PLAN SUBTOTAL			$8,798,300
Property Acquisition (10% of Property Cost)			879,800
PLAN TOTAL			$9,678,100

2. B.R. Construction Cost.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Earth Dam				
Clearing & Grubbing	40	acre	$ 2,000.00	$ 80,000
Stripping	390,200	s.y.	0.65	253,630
Common Excavation	434,600	c.y.	2.50	1,086,500
Compacted Random Fill	1,066,100	c.y.	2.50	2,665,250
Compacted Impervious Fill	583,600	c.y.	4.00	2,334,400

2. B.R. Construction Cost. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Compacted Filter and Transition Material	326,500	c.y.	10.00	3,265,000
Seeding, Fertilizing and Mulching	585,400	s.y.	0.23	134,642
Access Roadway (top of dam)	13,400	s.y.	7.85	105,190
Access Roadway (top of rail)	14,000	l.f.	1.50	105,000
SUBTOTAL				$10,029,612
Emergency Spillway				
Common Excavation	256,900	c.y.	2.50	642,250
Compacted Impervious Fill	44,400	c.y.	4.00	177,600
Compacted Filter and Transition Material	18,400	c.y.	10.00	184,000
18" Riprap	35,900	c.y.	17.00	610,300
Seeding, Fertilizing and Mulching	81,500	s.y.	0.23	18,745
Highway Relocation	2,700	l.f.	50.00	135,000
SUBTOTAL				$ 1,767,895
Ellicott St. Culvert				
Common Excavation		c.y.	2.50	
Concrete (reinforced)		c.y.	125.00	
Concrete Pipe (72" diam.)		l.f.	140.00	
Sluice Gate		l.s.		
SUBTOTAL				$ 49,800
Principal Outlet Works				
Common Excavation		c.y.	2.50	
Compacted Select Fill		c.y.	4.00	
Concrete (reinforced)		c.y.	125.00	
Fixed Wheel Sluice Gates and Misc. Fabrications		lbs.	1.50	
Sluice Gate Electric Lift		ea.	5,000.00	
Stop Logs (one set)		l.s.		
Steel Sheet Piling		s.f.	8.00	
24" Riprap with Bedding		s.y.	35.30	
Electrical Facilities		l.s.		
SUBTOTAL				$ 454,000

2. B.R. Construction Cost. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Railroad Floodgate				
Common Excavation		c.y.	$ 2.50	
Compacted Select Fill		c.y.	4.00	
Concrete (reinforced)		c.y.	125.00	
Floodgate & Guides		lbs.	1.50	
Floodgate Machinery		l.s.		
Machinery Housing		l.s.		
Steel Sheet Piling		s.f.	8.00	
Track Relocation		l.s.		
Electrical Facilities		l.s.		
Service Bridge				
SUBTOTAL				$ 564,000
Care of Water		l.s.		200,000
Mobilization and Preparatory Work		l.s.		650,000
PLAN SUBTOTAL				$13,715,300
Contingencies (15%)				2,057,300
PLAN SUBTOTAL				$15,772,600
Engineering & Design (10%)				1,577,300
Supervision & Administration (8.25%)				1,301,200
Interest During Construction (6-1/8%)				966,100
PLAN TOTAL				$19,617,200

3. Summary of First Cost for B.R. Plan.

Item	Amount
Total Property Cost	$ 9,678,100
Total Construction Cost	19,617,200
GRAND TOTAL	$29,295,300

4. Average Annual Cost for B.R. Plan.

Item	Amount
Amortization (.0614)	$1,798,700
Operation & Maintenance	50,000
GRAND TOTAL	$1,848,700

C7. BATAVIA RESERVOIR - ALABAMA RESERVOIR COMPOUND

1. B.R.-A.R.C. Property Cost.

a. Batavia Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	6,460	acre	$ 3,230,000
Land (easements)	1,730	acre	173,000
Land (extinguishment of mineral rights)	100	acre	350,000
Buildings (residential)	82	job	3,870,000
Structures (radio station)	1	job	50,000
Structures (pipeline station)	1	job	100,000
Farms (plant & equip.)	7	job	700,000
Sand & Gravel Operations (plant & equipment)	4	job	400,000
Relocations			
Power Line (9,000 ft.)	1	job	735,300
Settling Lagoon Compound	1	job	50,000
Private Recreation Facility	1	job	40,000
Elevation of 3 miles of County Roads includes 24 ft. culvert)			100,000
COMPONENT TOTAL			$8,798,300

b. Alabama Reservoir Compound.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)	45	acre	$ 22,500
Land (easement)	5500	acre	550,000
Buildings (residential)	9	job	315,000
Buildings (public & other)	1		50,000
COMPONENT SUBTOTAL			$ 937,500

c. B.R.-A.R.C. Plan.

Item	Amount
B.R. Component Total	$ 8,798,300
A.R.C. Component Total	937,500
COMPONENT SUBTOTAL	$ 9,735,800
Property Acquisition (10% of Property Cost)	973,600
PLAN TOTAL	$10,709,400

2. B.R.-A.R.C. Construction Cost.

a. Batavia Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Earth Dam				
Clearing & Grubbing	40	acre	$2,000.00	$ 80,000
Stripping	390,200	s.y.	0.65	253,630
Common Excavation	434,600	c.y.	2.50	1,086,500
Compacted Random Fill	1,066,100	c.y.	2.50	2,665,250
Compacted Impervious Fill	583,600	c.y.	4.00	2,334,400
Compacted Filter and Transition Material	326,500	c.y.	10.00	3,265,000
Seeding, Fertilizing and Mulching	585,400	s.y.	0.23	134,642
Access Roadway (top of dam)	13,400	s.y.	7.85	105,190
Access Roadway (guard rail)	14,000	l.f.	1.50	105,000
SUBTOTAL				$10,029,612
Emergency Spillway				
Common Excavation	256,900	c.y.	2.50	642,250
Compacted Impervious Fill	44,400	c.y.	4.00	177,600

2. B.R.-A.R.C. Construction Cost. (Cont'd)

a. Batavia Reservoir. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Compacted Filter and Transition Material	18,400	c.y.	10.00	184,000
18" Riprap	35,900	s.y.	17.00	610,300
Seeding, Fertilizing and Mulching	81,500	s.y.	0.23	18,745
Highway Relocation	2,700	l.f.	50.00	135,000
SUBTOTAL				$ 1,767,895
Ellicott St. Culvert				
Common Excavation		c.y.	2.50	
Common (reinforced)		c.y.	125.00	
Concrete Pipe (72")		l.f.	140.00	
Sluice Gate		l.s.		
SUBTOTAL				$ 49,800
Principal Outlet Works				
Common Excavation		c.y.	2.50	
Compacted Select Fill		c.y.	4.00	
Concrete (reinforced)		c.y.	125.00	
Fixed Wheel Sluice Gates & Misc. Fabrications		lbs.	1.50	
Sluice Gate Electric Lift				
Stop Logs (one set)		l.s.		
Steel Sheet Piling		s.f.	8.00	
24" Riprap with Bedding		s.y.	35.30	
Electrical Facilities		l.s.		
SUBTOTAL				$ 454,400
Railroad Floodgate				
Common Excavation		c.y.	2.50	
Compacted Select Fill		c.y.	4.00	

2. B.R.-A.R.C. Construction Cost. (Cont'd)

a. Batavia Reservoir. (Cont'd)

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Concrete (reinforced)		c.y.	125.00	
Floodgate & Guides		lbs.	1.50	
Floodgate Machinery		l.s.		
Machinery Housing		l.s.		
Steel Sheet Piling		s.f.	8.00	
Track Relocation		l.s.		
Electrical Facilities		l.s.		
Service Bridge		l.s.		
SUBTOTAL				$ 564,000
Care of Water		l.s.		200,000
Mobilization and Preparatory Work		l.s.		650,000
COMPONENT TOTAL				$13,715,700

b. Alabama Reservoir Compound.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Relocations (highway)		l.s.	$ 613,000	$ 613,000
Clearing and Grubbing	107	acre	2,000	214,000
Stripping	256,500	s.y.	0.65	166,725
Compacted Random Fill	2,143,000	c.y.	2.50	5,357,500
Reinforced Concrete for Inlet and Outlet Structures		l.s.	1,118,900	1,118,900
Seeding, Fertilizing & Mulching	108	acre	1,100	118,800
Common Excavation	812,000	c.y.	2.50	2,030,000
Mobilization and Demobilization		l.s.	481,000	481,000
COMPONENT TOTAL				$10,099,925

c. B.R. - A.R.C. Plan.

Item	Amount
B.R. Component Total	$13,715,700
A.R.C. Component Total	10,099,900
PLAN SUBTOTAL	$23,815,600
Contingencies (15%)	3,572,300
PLAN SUBTOTAL	$27,387,900
Engineering & Design (10%)	2,738,800
Supervision & Administration (7.5%)	2,054,100
Interest During Construction (6-1/8%)	1,677,500
PLAN TOTAL	$33,858,300

3. Summary of First Cost of B.R.-A.R.C. Plan.

Item	Amount
Total Property Cost	$10,709,400
Total Construction Cost	33,858,300
GRAND TOTAL	$44,567,700

4. Average Annual Cost of B.R.-A.R.C. Plan.

Item	Amount
Amortization (.0614)	$ 2,736,500
Operation & Maintenance	100,000
GRAND TOTAL	$ 2,836,500

C8. BATAVIA PROJECT MODIFICATION

1. B.P.M. Property Cost.

Item	Estimated Quantity	Unit	Estimated Cost
Land (fee simple)		job	$ 300,000
PLAN SUBTOTAL			300,000
Property Acquisition 10% of Property Cost)			30,000
PLAN TOTAL			$ 330,000

2. B.P.M. Construction Cost.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Relocations				
Removal of Existing Pavement	1,500	s.y.	1.30	$ 1,950
Headwalls	10	c.y.	1.00	1,000
Manholes	2	each	1,050	2,100
12-inch Sluice Gate	3	each	315	945
15-inch Sluice Gate	1	each	525	525
36-inch Sluice Gate	1	each	950	950
36-inch Culvert	150	l.f.	18.40	2,760
36-inch Automatic Drainage Gate	3	each	525	1,575
Gravel Base	520	c.y.	5.25	2,730
Asphalt Concrete	170	ton	13.20	2,244
Raise Manhole	1	each	315	315
Manhole	2	each	525	1,050
Manhole	1	each	1,050	1,050
SUBTOTAL				$19,194
Channels				
Clearing and Grubbing		l.s.		84,000
Excavation	140,000	c.y.	2.50	350,000
Compacted Fill	2,300	c.y.	2.50	5,750

2. B.P.M. Construction Cost.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
Dumped Riprap	19,100	c.y.	14.20	271,200
Gravel Bedding Course	8,050	c.y.	10.00	80,500
SUBTOTAL				$791,450
Levees				
Excavation for Embankment	4,400	c.y.	2.50	11,000
Embankment	23,600	c.y.	2.50	59,000
Dumped Riprap	1,470	c.y.	13.20	19,404
Gravel Bedding Course	550	c.y.	10.00	5,500
Seeding and Fertilizing	3	acre	1,100	3,300
SUBTOTAL				$ 98,204
Mobilization and Demobilization				50,000
PLAN SUBTOTAL				958,848
Contingencies (20%)				191,800
PLAN SUBTOTAL				1,150,600
Engineering & Design(10%)				115,000
Supervision & Administration (10%)				115,000
PLAN TOTAL				1,380,600

3. Summary of First Cost for B.P.M. Plan.

Item	Amount
Total Property Costs	$ 330,000
Total Construction Costs	1,380,600
GRAND TOTAL	$ 1,710,600

4. Average Annual Cost for B.P.M. Plan.

Item	Amount
Amortization (.0614)	$ 105,000
Operation and Maintenance	25,000
GRAND TOTAL	$ 130,000

BUFFALO METROPOLITAN AREA, NY
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1980

APPENDIX D

SELECTED PLAN

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

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SECTION I - GENERAL

D1. INTRODUCTION

Several multiple purpose and/or flood management reservoirs and a local protection project were considered for reduction of flood damages in Tonawanda Creek Watershed. Several reservoir sites and combinations of sites were studied and the most promising one, the Batavia Reservoir Compound (Modified), is discussed in detail in this appendix. The considered local protection project would provide levees, bank protection, and channel enlargement necessary to reduce flood damages in the city of Batavia. The location of each considered improvement is shown on Plate 5 of the Main Report.

The Batavia Reservoir Compound (Modified), the Selected Plan, would consist of a combination of two shallow detention reservoirs arranged in series. The reservoirs would be located within the flood plain between the village of Alexander and the city of Batavia. They are referred to as the upper reservoir and lower reservoir in this appendix. A detailed description of each reservoir and a plan of operation are contained in Section VII of the Main Report. The location of each reservoir is shown on Plate D1. All elevations shown in this appendix are referred to United States Coast and Geodetic Survey datum.

SECTION II - UPPER RESERVOIR

D2. UPPER RESERVOIR EMBANKMENT AND EMERGENCY SPILLWAY

The upper embankment would be located approximately 200 feet downstream of the Conrail Railroad embankment, formerly the Erie-Lackawanna embankment. The embankment would stretch 5,450 feet across the Tonawanda Creek valley to within a short distance from the hamlet of North Alexander. The location selected for the embankment has two advantages: the area to be occupied by the embankment is presently cleared of substantial vegetation and its nearness to the existing railroad embankment allows this embankment to blend in with the surrounding area, providing minimum disruption of transportation facilities and land utilization. The location for the upper reservoir embankment is shown on Plate D1.

The embankment would be designed to function as an emergency spillway with a top elevation of 922.5 in order to satisfy hydraulic requirements for the reservoir. Approximately 2 feet of water would flow over the embankment during a Standard Project Flood assuming a maximum pool elevation of 924.5.

A typical cross section for the upper embankment is shown on Plate D2. The section was conservatively developed with 1 vertical on 3 horizontal sideslopes. A conservative development process was followed because of the lack of geotechnical information pertaining to the site. The design of the cross section will be modified when more is known of the existing conditions. A 10-foot top width was utilized for most of the upper embankment in an effort to develop the most cost effective recommendation. The geotechnical design of the upper embankment is discussed in Appendix E, paragraph E5.2.

A principal outlet works, consisting of several gated conduits, would be constructed through the upper embankment. The outlet works are discussed in detail under paragraph D3.

A 16-foot wide access roadway would be provided along a portion of the top of the upper embankment. A 20-foot top width would be necessary to accommodate the access road. The access roadway is discussed in more detail under paragraph D4.1.

D3. PRINCIPAL OUTLET WORKS

D3.1 Control Structure

The principal outlet works for the upper reservoir would consist of a control structure, stilling basin, and outlet channel located at or near the intersection of the upper embankment and Tonawanda Creek.

The control structure would be a five-conduit reinforced concrete box culvert with adjacent inlet flume. The culvert would have capacity to pass flows of approximately 2,000 cubic feet per second under natural flow conditions and up to approximately 10,700 cubic feet per second under the 100-year flood condition when the upper pool reaches El. 922.5. The structure would be founded on a 3-foot layer of compacted select fill placed over the

natural subsoil. Each conduit would be 11 feet wide by 11 feet high and equipped with an electrically operable fixed wheel control gate. Each gate would be operated from controls mounted on the electric gate lift and/or from controls located in the equipment building at the west abutment. Each conduit would be provided with upstream and downstream bulkhead slots for maintenance dewatering during nonflood periods. One set of stoplogs would be provided to permit dewatering one conduit at a time. A steel sheet pile cutoff wall would be provided under the control structure to reduce groundwater seepage.

An upstream inlet flume would funnel water into the gated conduits. The inlet flume would consist of a reinforced concrete section, located adjacent to the control gates, and steel sheet pile wingwalls. The reinforced concrete section would be designed as a U-frame with an integral concrete floor slab. The short-height sheet pile wingwalls would be designed as free-standing cantilevered walls. The channel bottom between the wingwalls would be protected with 24-inch riprap placed on a 12-inch bedding layer. The riprap would extend from the concrete floor slab to a line 10 feet upstream of the wingwalls. Center piers and wingwalls would be designed to reduce contraction losses. A centerline profile through the principal outlet works, with approximate dimensions, is shown on Plate D4.

D3.2 Stilling Basin

The stilling basin would be a reinforced concrete structure 61 feet wide and 62 feet long. The basin would be designed to reduce the energy of water discharged from the control structure to within tolerable limits. Baffle blocks and a raised end sill would be utilized for this purpose. Gravity-type training walls would be provided for the entire length of the stilling basin. The entire structure would be founded on a 3-foot layer of compacted select fill placed over the natural subsoil. A profile through the stilling basin is shown on Plate D4.

D3.3 Outlet Channel

The meandering Tonawanda Creek channel immediately downstream from the upper embankment would be abandoned. A new outlet channel, starting at the stilling basin, would be excavated normal to the embankment in order to provide a gradual transition to natural channel conditions. The outlet channel bottom, flaring from a width of 71 feet at the stilling basin to 91 feet, would be protected with 24-inch riprap placed on a 12-inch bedding layer for a distance of approximately 100 feet. Thence, the channel would be narrowed to 50 feet to form a pilot channel for low flows. The 50-foot wide pilot channel with 1 vertical on 2.5 horizontal sideslopes would extend downstream an additional 1,100 feet to a junction with the existing creek channel. The abandoned creek channel would be utilized as a spoil area for waste material from clearing and stripping operations associated with the construction of the upper embankment and from clearing and snagging operations along the existing creek channel within the upper and lower reservoir.

D4. APPURTENANCES

D4.1 Access Roadway

A 16-foot wide access road would be provided across the top of the upper embankment. The roadway would run from State Route 98 to Tonawanda Creek, a distance of approximately 1,800 feet. The roadway would have light-duty bituminous pavement. Guardrails would be installed on both sides of the roadway along the emergency spillway, a distance of approximately 1,550 feet. The access road would provide for operation and maintenance of the principal outlet works.

D4.2 Miscellaneous Facilities

Electrical service to the principal outlet works would be provided by existing transmission lines along State Route 98 and underground cables laid in conduit along the top of the upper embankment. A 15-foot by 20-foot equipment building of simple design would be located along the access road at the west abutment. A standby electrical generator, capable of operating the principal outlet works, would be located in the equipment building. Appropriate heating, lighting, and communications equipment would be provided.

D4.3 Clearing and Snagging

The existing Tonawanda Creek channel between Railroad Avenue and the upper embankment would be cleared of snags and debris jams. Dead trees along the channel banks and overhanging, partially uprooted trees would also be removed. This work is expected to restore the creek to a natural channel capacity of approximately 2,000 cubic feet per second near the upper dam, thereby reducing the frequency of minor flooding. The debris removed from the creek channel would be buried in the abandoned sections of the creek channel downstream from the upper embankment.

D5. RELOCATIONS

The Conrail Railroad and roadways within the boundaries of the upper reservoir would be maintained in their present condition with the following exception: thru traffic on Old Creek Road would terminate at the upper embankment. Minor washouts, requiring post flood maintenance, could be anticipated along the railroad right-of-way and Old Creek Road. The local region near the upper reservoir has sufficient alternate roadways so that only minimal inconvenience to local residents would occur. Existing power and telephone lines within the reservoir would remain in place and are not expected to experience any adverse effects due to the anticipated short duration flooding. Real estate requirements and the relocation of several buildings within the upper reservoir are discussed in Section VII of the Main Report.

Downstream from the upper reservoir a section of Peaviner Road and the existing bridge over Tonawanda Creek would require relocation due to the realignment of the creek channel in the vicinity of the principal outlet works. Approximately 2,000 feet of roadway would be realigned and

reconstructed with a light-duty bituminous pavement. A 24-foot wide road with 10-foot shoulders would be provided. A 60-foot span highway bridge would be provided over the new outlet channel from the principal outlet works. The bridge would have reinforced concrete abutments and wingwalls and a precast concrete deck with a bituminous wearing surface.

SECTION III - LOWER RESERVOIR

D6. LOWER RESERVOIR EMBANKMENT AND EMERGENCY SPILLWAY

The lower embankment would be located between 500 feet and 3,100 feet south of the abandoned Conrail Railroad embankment, formerly the Lehigh Valley embankment. The embankment would stretch 5,600 feet across the Tonawanda Creek valley to within a short distance from the intersection of Route 98 and the abandoned railroad embankment. This represents a major change from the location previously proposed for the Batavia Reservoir Compound. The revised location, selected for the lower embankment, was chosen because of its minimal length and improved foundation conditions. The location for the lower reservoir embankment is shown on Plate D1.

The embankment would be designed to function as an emergency spillway with a top elevation of 900 from Creek Road westward for approximately 4,000 feet. The emergency spillway is required to satisfy hydraulic requirements for the reservoir. Approximately 2.6 feet of water would flow over the embankment during a Standard Project Flood assuming a maximum pool elevation of 902.6. From Creek Road to the east abutment, and for a short distance at the west abutment, the embankment would be designed as a nonoverflow section with a top elevation of 905.5 and grassed slopes.

Two typical cross sections for the emergency spillway and nonoverflow sections of the lower embankment are shown on Plate D3. Both cross sections have 1 vertical on 3 horizontal sideslopes that were conservatively selected to compensate for the lack of geotechnical information for the site. The design of these cross sections will be modified when more information becomes available. A 10-foot top width was utilized for most of the spillway section and for the nonoverflow sections of the lower embankment for economic reasons. The geotechnical design of the lower embankment is discussed in Appendix E, paragraph E5.3.

A principal outlet works, consisting of several gated conduits, would be constructed through the emergency spillway section of the lower embankment. The outlet works are discussed in detail under paragraph D7.

A 16-foot wide access roadway would be provided along a portion of the top of the emergency spillway section of the lower embankment. The top width would be increased to 20 feet to accommodate the access road. The access roadway is discussed in more detail under paragraph D8.2.

D7. PRINCIPAL OUTLET WORKS

D7.1 Control Structure

The principal outlet works for the lower reservoir would consist of a control structure, stilling basin, outlet channel, and inlet channel located approximately 900 feet east of the intersection of the lower embankment and Tonawanda Creek.

The control structure would be a four-conduit reinforced concrete box culvert with adjacent inlet flume. The culvert would have capacity to pass up to approximately 6,000 cubic feet per second under the 500-year flood condition when the lower pool reaches El.900. This corresponds to the maximum allowable channel discharge through the city of Batavia. The structure would be founded on a 3-foot layer of compacted select fill placed over the natural subsoil. Each conduit would be 11 feet wide by 11 feet high and equipped with an electrically operable fixed wheel control gate. Each gate would be operated from controls mounted on the electric gate lift and/or from controls located in the equipment building near Route 98. Each conduit would be provided with upstream and downstream bulkhead slots for maintenance dewatering during nonflood periods. One set of stoplogs would be provided to permit dewatering one conduit at a time. A steel sheet pile cutoff wall would be provided under the control structure to reduce groundwater seepage.

An upstream inlet flume would funnel water into the gated conduits. The inlet flume would consist of a reinforced concrete section, located adjacent to the control gates, and steel sheet pile wingwalls. The reinforced concrete section would be designed as a U-frame with an integral concrete floor slab. The short-height sheet pile wingwalls would be designed as free-standing cantilevered walls. The channel bottom between the wingwalls would be protected with 24-inch riprap placed on a 12-inch bedding layer. The riprap would extend from the concrete floor slab to a line 10 feet upstream of the wingwalls. Center piers and wingwalls would be designed to reduce contraction losses. A centerline profile through the principal outlet works, with approximate dimensions, is shown on Plate D4.

D7.2 Stilling Basin and Outlet Channel

The stilling basin would be a reinforced concrete structure 48.5 feet wide and 62 feet long. The basin would be designed to reduce the energy of water discharged from the control structure to within tolerable limits. Baffle blocks and a raised end sill would be utilized for this purpose. Gravity-type training walls would be provided for the entire length of the stilling basin. The entire structure would be founded on a 3-foot layer of compacted select fill placed over the natural subsoil. A new outlet channel, starting at the spilling basin, would be excavated normal to the lower embankment. The 70-foot wide channel with 1 vertical on 2 horizontal sideslopes would extend downstream for approximately 100 feet to a junction with the existing creek channel. The outlet channel bottom, flaring from a width of 48.5 feet at the stilling basin to 70 feet, would be protected with 24-inch riprap placed on a 12-inch bedding layer for its total length. A profile through the stilling basin and outlet channel is shown on Plate D4.

D7.3 Inlet Channel

The meandering Tonawanda Creek channel immediately upstream from the lower embankment and west of the principal outlet works would be abandoned. A new inlet channel, starting at the inlet flume, would be excavated normal to the embankment in order to provide a gradual transition to natural channel conditions. The 70-foot wide channel with 1 vertical on 2 horizontal sideslopes would extend upstream for approximately 500 feet to a junction

with the existing creek channel. The abandoned creek channel would be utilized as a spoil area for waste material from clearing and stripping operations associated with the construction of the lower embankment and from clearing and snagging operations along the existing creek channel within the upper and lower reservoir.

D8. APPURTENANCES

D8.1 Training Dikes

Several training dikes would be located along the east and west sides of the Tonawanda Creek valley. Along the east side, a dike would stretch 950 feet across a natural saddle located approximately 1,000 feet south of East Road. Along the west side, three dikes would be located approximately 500 feet east of Route 98 in the reach between Cookson Road and the former Lehigh Valley Railroad embankment. These dikes would stretch 3,330 feet, 600 feet, and 150 feet across low areas in order to prevent possible overtopping of Route 98. The locations for the training dikes are shown on Plate D1.

Each dike would be designed as a nonoverflow section with a top elevation of 905.5 and grassed slopes. A cross section with 1 vertical on 3 horizontal sideslopes was conservatively selected to compensate for the lack of geotechnical information for the sites. The design will be modified when more information becomes available. A 10-foot top width was utilized for economic reasons. The maximum height of these dikes varies from 5.5 feet to 9 feet. The geotechnical design of the training dikes is discussed in Appendix E, paragraph E5.5.

Natural drainage from small areas adjacent to the lower reservoir would be cut off by the training dikes. A gated culvert would be constructed through each dike to provide the required interior drainage. During periods of flooding, the culverts would function in reverse to prevent a flood pool from inundating the area adjacent to the reservoir. The culverts would be positioned in the dikes at natural low points. The culverts would consist of 24-inch to 36-inch diameter reinforced concrete pipe, reinforced concrete headwalls and wingwalls, and automatic flap gates mounted on the reservoir side of each dike.

D8.2 Access Roadway

A 16-foot wide access road would be provided across the top of the lower reservoir embankment. The roadway would run from Creek Road to Tonawanda Creek, a distance of approximately 820 feet. The roadway would have light-duty bituminous pavement. Guardrails would be installed on both sides of the roadway along the emergency spillway. The access road would provide for operation and maintenance of the principal outlet works.

D8.3 Miscellaneous Facilities

Electrical service to the principal outlet works would be provided by existing transmission lines along State Route 98 and underground cables laid in conduit along the top of the lower embankment. A 15-foot by 20-foot

equipment building of simple design would be located near Route 98. A standby electrical generator, capable of operating the principal outlet works, would be located in the equipment building. Appropriate heating, lighting, and communications equipment would be provided.

D8.4 Clearing and Snagging

The existing Tonawanda Creek channel within the lower reservoir would be cleared of snags and debris jams. Dead trees along the channel banks and overhanging, partially uprooted trees would also be removed. This work is expected to restore the creek to a natural channel capacity of approximately 2,000 cubic feet per second near the upper dam, thereby reducing the frequency of minor flooding. The debris removed from the creek channel would be buried in the abandoned sections of the creek channel downstream from the upper embankment and upstream from the lower embankment.

D8.5 Bridge Removal

The abandoned Conrail Railroad bridge, formerly the Lehigh Valley bridge, over Tonawanda Creek would be removed in order to improve hydraulic conditions downstream of the lower reservoir. The bridge superstructure and abutments would be demolished. In addition, the creek banks adjacent to the abutments would be excavated to stable 1 vertical on 2 horizontal sideslopes.

D9. RELOCATIONS

Roadways within the boundaries of the lower reservoir would be maintained in their present condition. Minor washouts, requiring post flood maintenance, could be anticipated along several of the light-duty roadways within the reservoir. The local region near the lower reservoir is considered to have sufficient alternate roadways so that only minimal inconveniences to local residents would occur. No major east-west highways cross the lower reservoir. Existing power and telephone lines within the reservoir would remain in place and are not expected to experience any adverse effects due to the anticipated short-duration flooding. However, sections of these lines and a remote controlled radio transmitter may require relocation after more detailed analysis and consultation with the affected utilities during advanced engineering and design. Real estate requirements and the relocation of residences, farms, and businesses situated within the lower reservoir are discussed in Section VII of the Main Report.

A section of Creek Road in the vicinity of its intersection with the lower embankment would require relocation due to embankment construction. Approximately 500 feet of roadway would be realigned vertically in order to cross over the lower embankment. A 24-foot wide road with 10-foot shoulders and guardrails on both sides would be provided. The roadway would have light-duty bituminous pavement.

SECTION IV - ESTIMATE OF COST

D10. ESTIMATE OF COST

A detailed estimate of property costs for the Batavia Reservoir Compound (Modified) is shown in Table D1. Estimates of costs for lands, easements, and structures are based on current market values as determined from consultations with local realtors and tax assessors. Property acquisition costs and contingency allowances were estimated at 10 percent and 15 percent respectively, and added to obtain the total first cost of property.

A detailed estimate of construction costs for the Batavia Reservoir Compound (Modified) is shown in Table D2. The estimate is based on current costs of similar construction projects, adjusted to June 1980 prices. An estimate of approximately 15 percent was applied as an allowance for contingencies to obtain the total direct cost of required work. Indirect costs for engineering and design, and construction, supervision and administration were estimated to be 15 percent and 10.5 percent respectively, of total direct cost and added to obtain the total first cost of construction assuming that both reservoirs were advertised, bid, and constructed concurrently.

A summary of first costs and investment costs for the Batavia Reservoir Compound (Modified) is shown on Table D3. Total investment includes simple interest of 7-3/8 percent applied for 1 year on initial property requirements and total first cost of required construction. Initial property requirements include land (fee simple) and total acquisition costs.

D11. ANNUAL OPERATION, MAINTENANCE, AND MAJOR REPAIR

The annual operation, maintenance, and major repair (OM&R) costs for the Batavia Reservoir Compound (Modified) were estimated by considering similar data developed for other Corps of Engineers projects. The OM&R costs include the services of a permanent staff and temporary seasonal employees, and also the costs of land management, fish and wildlife management, necessary equipment, normal repairs, periodic major repair, and engineering services. A detailed discussion of OM&R activities is given in Section VII of the Main Report. The average annual OM&R ccsts for the Batavia Reservoir Compound are estimated to be $275,000.

D12. ANNUAL COSTS

The average annual costs for the Batavia Reservoir Compound (Modified) are shown in Table D3. Annual costs include 7-3/8 percent interest on investment, amortization of investment over an economic life of 100 years, and operation, maintenance, and major repair costs. The average annual cost of the Batavia Reservoir Compound is estimated to be $2,043,000.

Table D1 - Estimated Property Costs for Batavia Reservoir Compound (Modified)

1. Upper Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
			$
Land (fee simple)	50	Acre	32,000
Fish and Wildlife Compensation Lands	350	Acre	148,000
Land (permanent easement)	895	Acre	380,000
Buildings (residential)	8	Each	382,000
COMPONENT TOTAL			942,000

2. Lower Reservoir.

Item	Estimated Quantity	Unit	Estimated Cost
			$
Land (fee simple)	50	Acre	32,000
Land (upstream permanent easement)	3,070	Acre	1,302,000
Land (downstream permanent easement) 1/	800	Acre	170,000
Fish and Wildlife Compensation Lands	350	Acre	148,000
Buildings (residential)	37	Each	1,765,000
Farms and Businesses (plant and equipment)	4	Each	530,000
COMPONENT TOTAL			3,947,000

1/ Downstream permanent easements required to prevent future development in existing natural ponding area.

3. Summary.

Item	Amount
	$
U. R. Component Total	942,000
L. R. Component Total	3,947,000
Total	4,889,000
Property Acquisition (10%)	489,000
Contingencies (15%)	732,000
TOTAL PROPERTY COST	6,110,000

Table D2 - Estimated Construction Costs for Batavia Reservoir Compound (Modified)

1. Upper Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
			$	$
Earth Dam and Emergency Spillway				
Clearing and Grubbing	50	Acre	1,900.00	95,000
Stripping	87,800	S.Y.	0.90	79,020
Common Excavation	54,600	C.Y.	3.50	191,100
Compacted Impervious Fill	87,100	C.Y.	8.20	714,200
Compacted Random Fill	97,600	C.Y.	3.45	336,720
Compacted Filter Material	21,900	C.Y.	11.85	259,515
12-inch Riprap with Bedding	44,900	S.Y.	19.30	866,570
18-inch Riprap with Bedding	55,500	S.Y.	34.00	1,887,000
Topsoil	16,700	C.Y.	9.50	158,650
Seed (Crownvetch), Fertilize, and Mulch	100,200	S.Y.	0.65	65,130
Access Roadway - Top of Dam	3,200	S.Y.	12.25	39,200
Access Roadway - Guard Rail	3,100	L.F.	13.90	43,090
Subtotal				4,735,195
Principal Outlet Works				
Common Excavation	8,500	C.Y.	3.50	29,750
Compacted Select Fill	1,600	C.Y.	10.50	16,800
Concrete (reinforced)	2,015	C.Y.	175.00	352,625
Fixed Wheel Sluice Gates and Miscellaneous Fabrications	45,500	LBS.	2.10	95,550
Sluice Gate Electric Lift	5	Each	7,000.00	35,000
Stop Logs (one set)	-	L.S.	14,000.00	14,000
Steel Sheet Piling	2,800	S.F.	11.10	31,080
24-inch Riprap with Bedding	1,150	S.Y.	44.85	51,578
Electrical Facilities	-	L.S.	117,950.00	117,950
Common Excavation (Outlet Channel)	19,800	C.Y.	3.50	69,300
Subtotal				813,633

Table D2 - Estimated Construction Costs for Batavia Reservoir Compound (Modified) (Cont'd)

1. Upper Reservoir (Cont'd).

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
			$	$
Hydro-Meteologic Data Network System				
Installation of Telemarked River Gages	2	Each	11,800.00	23,600
Converting Existing River Gages to Telemark	4	Each	4,825.00	19,300
Move Alabama Gage Downstream to Foote Road	-	L.S.	3,200.00	3,200
Reservoir Stage Gage	1	Each	6,400.00	6,400
Telemarked Rain Gages	4	Each	2,150.00	8,600
Subtotal				61,100
Miscellaneous Work				
Highway Relocation	5,400	S.Y.	12.25	66,150
Bridge Relocation	-	L.S.	54,000.00	54,000
Seed, Fertilize, and Mulch	154,300	S.Y.	0.45	69,435
Care of Water	-	L.S.	43,000.00	43,000
Clearing and Snagging	5	Mile	18,700.00	93,500
Mobilization and Preparatory Work	-	L.S.	386,000.00	386,000
Subtotal				712,085
COMPONENT TOTAL				6,322,013

Table D2 - Estimated Construction Costs for Batavia Reservoir Compound (Modified) (Cont'd)

2. Lower Reservoir.

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
			$	$
Earth Dam and Emergency Spillway				
Clearing and Grubbing	45	Acre	1,900.00	85,500
Stripping	64,000	S.Y.	0.90	57,600
Common Excavation	142,200	C.Y.	3.50	497,700
Compacted Impervious Fill	41,700	C.Y.	8.20	341,940
Compacted Random Fill	28,300	C.Y.	3.45	97,635
Compacted Filter Material	11,700	C.Y.	11.85	138,645
12-inch Riprap with Bedding	29,500	S.Y.	19.30	569,350
18-inch Riprap with Bedding	34,000	S.Y.	34.00	1,156,000
Topsoil	9,700	C.Y.	9.50	92,150
Seed (Crownvetch), Fertilize, and Mulch	59,000	S.Y.	0.65	38,350
Access Roadway - Top of Dam	1,500	S.Y.	12.25	18,375
Access Roadway - Guard Rail	1,700	L.F.	13.90	23,630
Subtotal				3,116,875
Principal Outlet Works				
Common Excavation	12,000	C.Y.	3.50	42,000
Compacted Select Fill	1,250	C.Y.	10.50	13,125
Concrete (reinforced)	1,600	C.Y.	175.00	280,000
Fixed Wheel Sluice Gates and Miscellaneous Fabrications	33,000	LBS.	2.10	69,300
Sluice Gate Electric Lift	4	Each	7,000.00	28,000
Stop Logs (one set)	-	L.S.	14,000.00	14,000
Steel Sheet Piling	2,600	S.F.	11.10	28,860
24-inch Riprap with Bedding	1,050	S.Y.	44.85	47,093
Electrical Facilities	-	L.S.	193,000.00	193,000
Common Excavation (Inlet Channel)	12,800	C.Y.	3.50	44,800
Subtotal				760,178

Table D2 - Estimated Construction Costs for Batavia Reservoir Compound (Modified) (Cont'd)

2. Lower Reservoir (Cont'd).

Item	Estimated Quantity	Unit	Unit Cost	Estimated Cost
			$	$
Training Dikes				
Clearing and Grubbing	20	Acre	1,900.00	38,000
Stripping	30,800	S.Y.	0.90	27,720
Common Excavation	5,800	C.Y.	3.50	20,300
Compacted Impervious Fill	23,200	C.Y.	8.20	190,240
Compacted Random Fill	13,700	C.Y.	3.45	47,265
Topsoil	6,300	C.Y.	9.50	59,850
Concrete Pipe (24-inch diam.)	165	L.F.	35.00	5,775
Concrete Pipe (36-inch diam.)	35	L.F.	65.00	2,275
Concrete (reinforced)	45	C.Y.	175.00	7,875
Flap Gate (24-inch diam.)	3	Each	2,200.00	6,600
Flap Gate (36-inch diam.)	1	Each	3,600.00	3,600
Seed, Fertilize, and Mulch	96,800	S.Y.	0.45	43,560
Subtotal				453,060
Highway Relocation				
Compacted Random Fill	3,000	C.Y.	3.45	10,350
Highway Relocation	1,600	S.Y.	12.25	19,600
Guardrail	1,000	L.F.	13.90	13,900
Subtotal				43,850
LVRR Bridge Removal				
Demolition - Abutments	870	C.Y.	28.15	24,490
Demolition - Superstructure	-	L.S.	108,000.00	108,000
Common Excavation	5,100	C.Y.	3.50	17,850
Subtotal				150,340
Miscellaneous Work				
Seed, Fertilize, and Mulch	167,000	S.Y.	0.45	75,150
Care of Water	-	L.S.	86,000.00	86,000
Clearing and Snagging	8	Mile	18,700.00	149,600
Reservoir Stage Gage	1	Each	6,400.00	6,400
Mobilization and Preparatory Work	-	L.S.	315,000.00	315,000
Subtotal				632,150
COMPONENT TOTAL				5,156,453

Table D2 - Estimated Construction Costs for Batavia Reservoir Compound (Modified) (Cont'd)

3. Summary.

Item	Amount
	$
U. R. Component Total	6,322,013
L. R. Component Total	5,156,453
Plan Subtotal	11,478,466
Contingencies (15%)	1,721,534
TOTAL DIRECT COST	13,200,000
Engineering and Design (15%)	1,980,000
Supervision and Administration (10.5%)	1,390,000
TOTAL CONSTRUCTION COST	16,570,000

Table D3 - Summary of Estimated Costs for Batavia Reservoir Compound (Modified)

1. First Cost.

Item	Amount
	$
Property	6,110,000
Construction	16,570,000
TOTAL	22,680,000

2. Investment Cost.

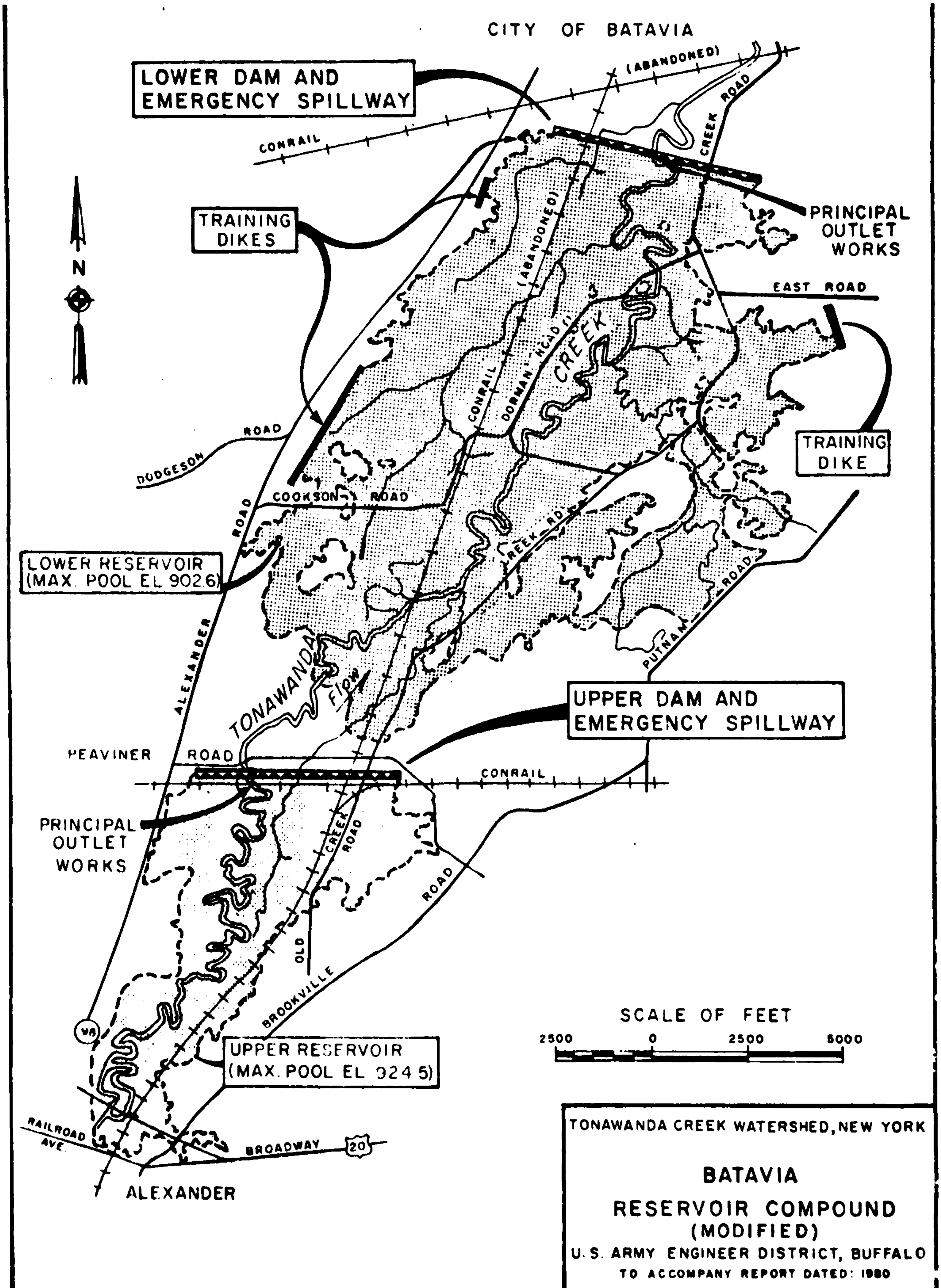
Item	Amount
	$
Property	6,110,000
Construction	16,570,000
Subtotal	22,680,000
Interest During Construction (7-3/8%) 1/ 2/	1,263,000
TOTAL	23,943,000

1/ Includes land (fee simple) and total property acquisition costs, equal to $553,000, and construction cost.

2/ Assume 2-year construction period.

3. Average Annual Cost.

Item	Amount
	$
Interest (7-3/8%)	1,766,000
Amortization (0.00007)	2,000
Operation and Maintenance	275,000
TOTAL	2,043,000



TONAWANDA CREEK WATERSHED, NEW YORK

BATAVIA

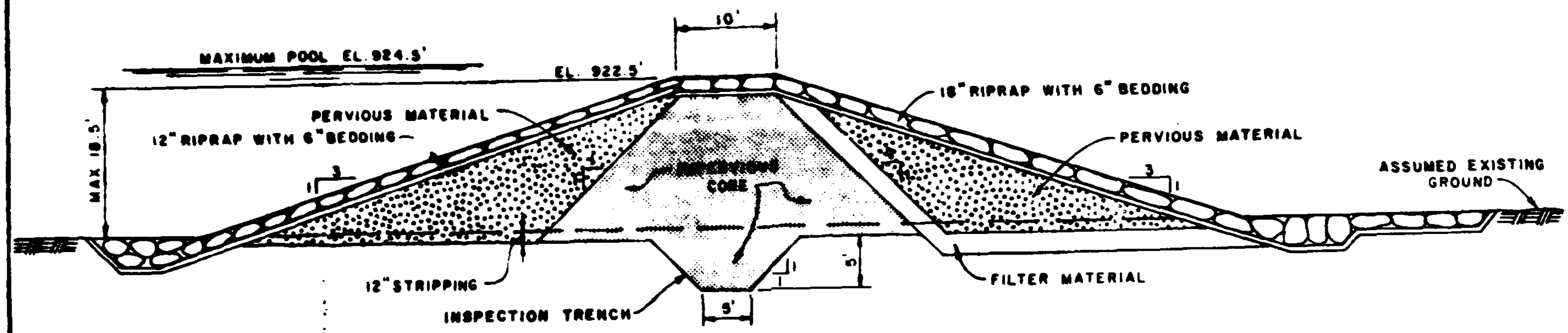
RESERVOIR COMPOUND

(MODIFIED)

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED: 1980

PLATE D1



EMERGENCY SPILLWAY

SCALE 1" = 10'

10' 0 10' 20'

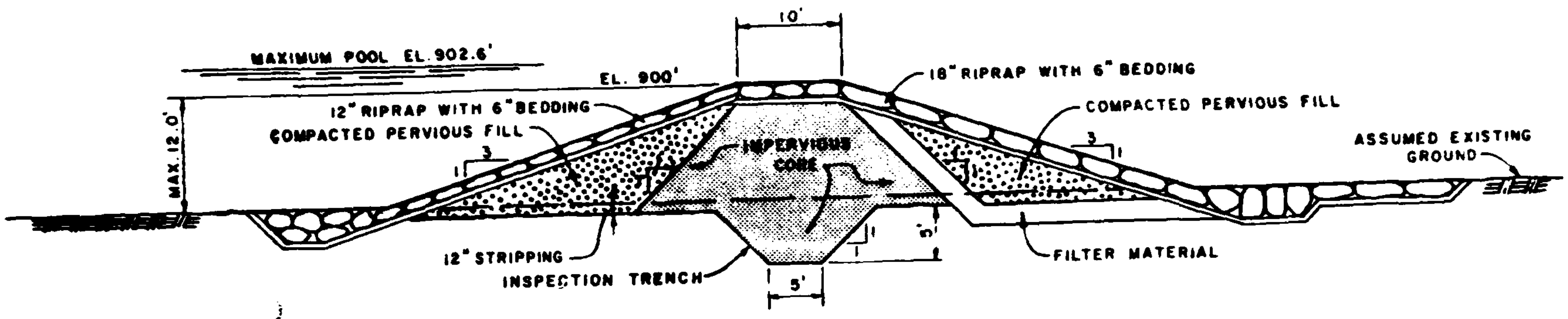
BATAVIA RESERVOIR COMPOUND (MODIFIED)

TONAWANDA CREEK WATERSHED, N.Y.
BATAVIA RESERVOIR COMPOUND

UPPER RESERVOIR
EMBANKMENT
CROSS SECTION

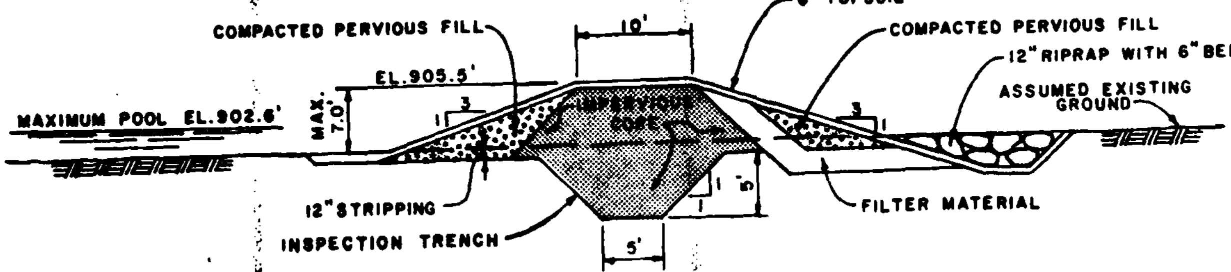
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1980

PLATE D2



EMERGENCY SPILLWAY

SCALE 1" = 10'



TYPICAL NONOVERFLOW SECTION

SCALE 1" = 10'

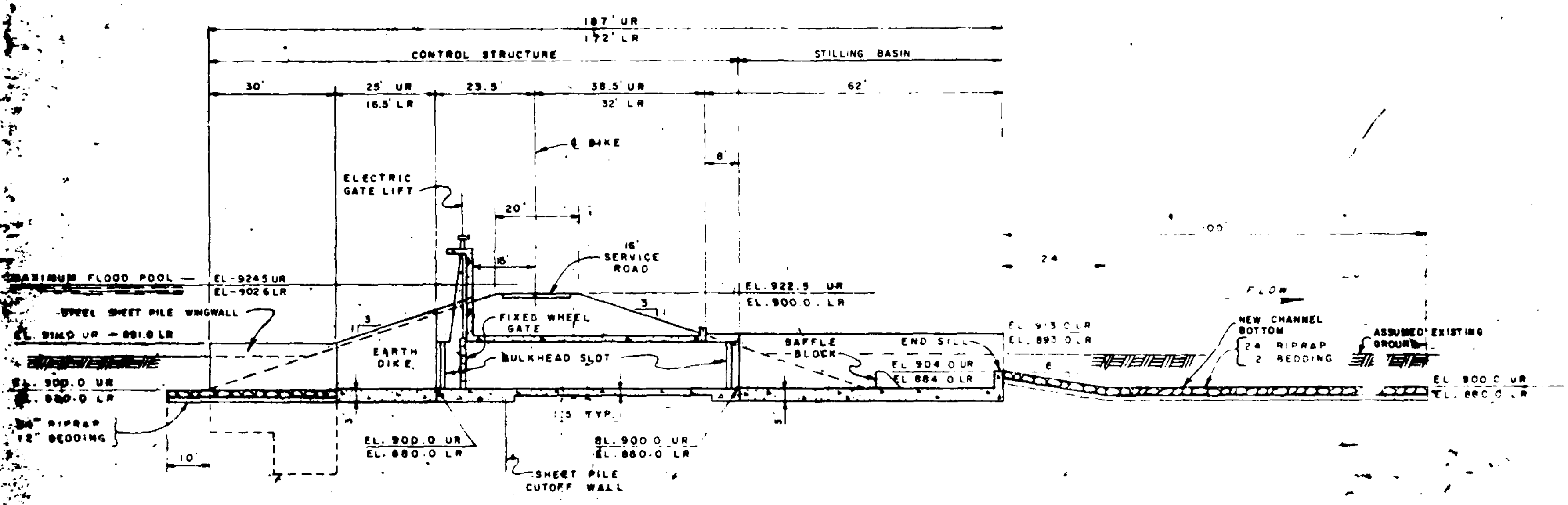
BATAVIA RESERVOIR COMPOUND (MODIFIED)

TONAWANDA CREEK WATERSHED, N.Y.
BATAVIA RESERVOIR COMPOUND

LOWER RESERVOIR EMBANKMENT CROSS SECTIONS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1980

PLATE D3



PRINCIPAL OUTLET WORKS

(CENTERLINE PROFILE OF TYPICAL CONDUIT)

NOT TO SCALE

UPPER RESERVOIR (UR): 5 – 11' X 11' GATED CONDUITS
LOWER RESERVOIR (LR): 4 – 11' X 11' GATED CONDUITS

TONAWANDA CREEK WATERSHED, NEW YORK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

PRINCIPAL OUTLET WORKS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED, 1980

PLATE D4

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1980

APPENDIX E

GEOTECHNICAL DESIGN

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

APPENDIX E

GEOTECHNICAL DESIGN

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APPENDIX E
GEOTECHNICAL DESIGN

SECTION I - GENERAL

E1. INTRODUCTION

The Batavia Reservoir Compound (Modified), the selected plan, is a combination of two shallow detention reservoirs arranged in series. The reservoirs are located within the flood plain between the village of Alexander and the city of Batavia. They are referred to as the upper reservoir and lower reservoir in this appendix. The location of each reservoir is shown on Plate E1. All elevations shown in this appendix are referred to United States Coast and Geodetic Survey datum.

SECTION II - GEOLOGY AND SOILS

E2. REGIONAL GEOLOGY

E.2.1 Physiography

The proposed dam sites are located in the towns of Batavia and Alexander, Genesee County, NY. This area is within the Erie-Ontario Plain of the Central Lowlands physiographic province (Plate E1). Topography is relatively flat to gently rolling except for linear features such as moraines, beach ridges, and bedrock outcrops. The Onondaga escarpment is the most prominent of the latter, and crosses just north of the project. The moraines in the area are late Wisconsinan in age and are generally composed of till. Glacial Lake Warren formed the most outstanding beach ridges at an elevation of 850 to 900 feet above sea level.

Tonawanda Creek, a tributary to the Niagara River, provides the major drainage through the area. Its upper reach, south of the project area, drains a narrow, glacially-filled valley. Its lower portion flows through the bed of a former lake, Lake Tonawanda, which existed up until about 700 years ago. In the project vicinity it flows through a relatively wide alluvial plain.

E2.2 Surficial Geology

Surficial deposits in the area are greatly influenced by glacial processes of the Late Wisconsinan Stage, particularly those activities which occurred about 13,000 years ago. Advance and retreat of ice directly deposited till, morainal ridges, and gravelly kames and outwash. Preglacial lakes in the narrow valleys were filled with clay and silt and gravelly deltas. The glacial Great Lakes such as Lakes Whittlesey and Warren left remnants of their beaches. Lake Tonawanda, which occupied a shallow depression north of the Onondaga escarpment is now swampy and filled with fine-grained and organic deposits.

Alluvium in the form of gravel bars and silt overbank deposits is common.

E2.3 Bedrock Geology

Western New York is underlain by Paleozoic sandstone, siltstone, shale, and carbonate rocks. The general stratigraphy is shown on Plate E1. The Silurian Lockport Dolomite and Devonian Onondaga Limestone are the major ridge formers. These, along with the Medina Sandstone, are primary sources of quarried stone. The Silurian Salina Formation is also of economic importance. The nearby Retsof Salt Mine, located within the Salina Formation is one of the world's largest producers of salt. Several formations, especially the Medina and Lockport, provide reservoirs for natural gas production.

E2.4 Structural Geology

Bedrock forms a south-southwestward dipping homocline. Small scale folds related to gravity creep may be found. Joints are common usually occurring

as two diagonal sets trending N45°W and N75°E (Sutton, 1950). The major structure in the area is the Clarendon-Lindon Fault System (Figure E1). According to Fakundiny and Others (1978), this system forms a 3 to 9.3 mile wide zone of complexly arranged steeply dipping reverse and normal faults in Pre-Cambrian and Paleozonic rock. They measured about 3,300 feet of vertical displacement and consider it to be possibly the longest and oldest active fault in the eastern United States.

E2.5 Ground Water

Large quantities of ground water are available in the region. The carbonate bedrock and glacially deposited gravel form large aquifers. Many municipalities, as well as single homeowners, use ground water as their primary source of water.

E2.6 Seismicity

Northwestern New York is located in an area classified as a Seismic Risk Zone 3 (Figure E2). This is defined as an area where major damage could occur due to seismic activity. The greatest recorded earthquake occurring at Attica, NY, in 1929, had an intensity of VIII on the Modified Mercalli Scale. According to published reports, 251 house chimneys were thrown down and walls were cracked. In a small cemetery east of town, practically every monument went down. Westward of Attica Reservoir, a number of wells went dry and in the reservoir there was a sudden increase of about 1,000,000 gallons per day without any rain; this flow continued for some days. In Batavia, several house chimneys fell and a small lake overflowed a highway. Figure E3 shows the location of earthquake epicenters in the Attica, NY, area. In addition to those shown, there was another earthquake at Dale, NY, in 1973 which has been related to well injection (Fakundiny and Others, 1978).

E3. LOCAL GEOLOGY

E3.1 Surficial Geology

The Tonawanda Creek valley between Batavia and Alexander, NY, is largely filled with stratified gravel, sand, and silt. Poorly drained, low-lying areas are typically filled with organic silty alluvium. Some of these organic deposits are more than 3 feet thick (U. S. Soil Conservation Service, 1969) and probably developed in depressions left in glacial outwash.

The topography of the valley north of Alexander is low except for several kames (Plate E1). These knobby ridges were deposited by glacial ice and are composed of stratified, well-sorted sand and gravel. Some kames are overlain by sandy silt till. The kames have as much as 100 feet of relief and are utilized as borrow areas for sand and gravel (Photo E1).

Many low areas adjacent to the kames are also composed of sand and gravel. These deposits are glacial outwash, inwash to glacial Great Lakes, and alluvium.

The lower dam site (Plate E3) is located on outwash and beach deposits. The beach deposit (Boring D79-3) is composed of well sorted medium sand and is about 21.5 feet thick.

The upland adjacent to the valley is blanketed with sandy silt till. This material appears to be uniformly distributed to the south and east of the valley but is in the form of hummocky end moraine to the west. Low areas between hummocks are poorly drained causing swampy conditions.

E3.2 Bedrock

Bedrock underlying the project area consists of the Levanna Shale member of the Middle Devonian Skaneateles Formation. Grossman (1938) reports a thickness of 128 feet for this member in the Batavia, NY, area. Sutton (1950) describes the basal part of the member as a black, bituminous shale containing the brachiopod Orbiculoidea minuta in great numbers. Twenty-three feet from the base is a brownish-gray, crystalline, fossiliferous limestone, 1-3/10 of a foot thick. Above the limestone is a dark to medium gray shale; upper portions of which are characterized by dark gray, irregularly bedded, fossiliferous shale.

No outcrops were observed in the project area but bedrock was encountered at borings taken along the lower dam alignment.

E3.3 Ground Water

Ground water is relatively close to the surface and is generally encountered within 5 feet of the surface. Water levels are probably controlled mostly by the stage of Tonawanda Creek. Most soils are very permeable. This may result in the need for considering dewatering techniques in excavations. Observation wells were installed in the vicinity of the center of both proposed dams so that ground water processes can be studied.

E3.4 Structural Geology

Bedrock underlying the project site is assumed to follow the regional dip of about 3° to the south. Conners (1969) notes that as one approaches the Clarendon-Linden fault structure, which he maps about 2,000 feet east of the lower dam site and 3 miles from the upper dam site, the dip may change to as much as 3-5° to the west. The effects of this geological structure and its associated seismicity have been considered in the preliminary designs for the embankments.

E3.5 Fluvial Processes

Tonawanda Creek is the major drainage way through the area. In its upstream reaches where it flows through a valley filled with glacial deposits it carries some bedload. In its lower reaches, particularly south of Alexander, it carries mostly washload. This material is deposited at times when the stream overflows its banks. Archer and La Sala (1968) shows the gradation of two suspended sediment samples taken in 1963 to be 58 and 78 percent clay, 41 and 15 percent silt, and 1 and 7 percent sand.

The banks of Tonawanda Creek in the project vicinity are low, relatively stable, and composed of fine sand. Their relative stability is probably due to low velocities of the stream.

La Sala (1968), calculates that 60,000 tons of sediment, mostly clay, is annually discharged at Tonawanda Creek in Batavia. He observed that reservoirs constructed on the creek may experience problems due to the sediment load. The anticipated volume and distribution of sediment accumulation at the upper and lower dams are unknown.

To evaluate the magnitude of sedimentation problems which may occur during periods of extended storage, samples will be taken during detail design at appropriate intervals to determine its concentration and gradation. The volume of sediment and distribution of deposits will be calculated so the maintenance requirements may be determined.

We will also consider the effects that sediment storage and controlling of stream stage will have on the bed and banks downstream of the proposed structures. Some erosion of banks, especially those composed of silts, probably would occur.

E4. SUBSURFACE EXPLORATIONS

E4.1 General

A subsurface exploration program was conducted in 1979 to obtain the soils information necessary to perform a preliminary design for the proposed flood control project.

E4.2 1979 Program

A subsurface exploration program for the Batavia Reservoir Compound was conducted in May 1979. The borings and their locations are shown on Plate E1. The primary purpose of this drilling program was to estimate the liquefaction potential of the soils by their relative density as determined by the Standard Penetration Test (Seed and Idriss, 1971). This method provided us with data to evaluate the suitability of the proposed sites.

The soil borings were conducted using a 3.5-inch outer diameter (O.D.) sampler driven 18 inches by a 375 pound hammer free falling 18 inches. Blow counts were recorded every 6 inches of penetration. When gravel was encountered in the sampler, the amount of penetration per blow was recorded for each drive. This was done to eliminate any resistance due to gravel during driving of the Split Spoon Sampler. Continuous Split Spoon Samples were obtained at each borehole location.

E4.3 Vicinity Programs

Previous subsurface explorations were made in 1974 by the New York State Department of Transportation, in 1950 and 1959 by the New York State Department of Public Works, and in 1971 by the Niagara Mohawk Power Company in the general vicinity of the project. The maximum depth of these borings

is 76 feet. Bedrock was encountered at a depth of approximately 70 feet, just east of the city of Batavia at the crossing of the Conrail railroad line and State Route 63. Rock was encountered at a depth of approximately 20 feet just west of Batavia at the crossing of the Conrail railroad line and State Route 98. Logs of rock samples obtained there indicated that the bedrock consists of a shaley limestone.

E.4.4 Laboratory Testing

Laboratory tests were performed on the disturbed soil samples obtained in the 1979 program. These tests consisted of Atterberg Limits, Gradation Analysis, and Moisture Content. Classification of the soil samples was performed using the Unified Classification System (see Plate E2). Data obtained from the testing program was used for a preliminary determination of the liquefaction potential of the soil and preliminary design of the structures.

E4.5 Soils Stratigraphy

The material underneath the axis of the upper dam consists mainly of sandy silt underlain by gravelly sand. Underlying the gravelly sand is a layer of clayey silt which grades into gravelly fine sand. No bedrock was encountered. The east abutment of the upper dam generally consists of a gravelly sand underlain by a clayey silt. No bedrock was encountered at this location (Plate E4).

The material beneath the axis of the lower dam consists of gravelly silty sand underlain by shale. Shale was encountered at approximately 30 feet below ground surface (Plate E3).

The material underneath the west training dike is a sorted glacial outwash consisting of sandy to silty gravels. The water table was encountered at approximately 6 feet below ground surface and had a distinct sulphur odor. No bedrock was encountered. Underneath the east training dike the material consists of glacial outwash of stratified layers of sand and gravel overlying till. The water table was approximately 8 feet below ground surface and no bedrock was encountered.

E5. GEOTECHNICAL DESIGN

E5.1 General

A preliminary design for the Batavia Reservoir Compound (Modified), was performed for the upper and lower reservoir embankments as well as for the training dikes located on both the east and west side of the valley. Seepage through the embankments was not analyzed nor were the various cases for stability. This will be accomplished in the next phase as well as a detailed seismic analysis of the embankments and foundation materials.

E5.2 Upper Reservoir Embankment

The upper embankment will be located approximately 200 feet downstream of the Conrail railroad embankment. The reservoir embankment will stretch

approximately 5,450 feet across the Tonawanda Creek Valley. The location for the upper reservoir embankment is shown on Plate E1. The embankment has been designed to function as an emergency spillway with a top elevation of 922.5 feet.

The embankment (Plates E3 and E6) was developed with a one vertical on three horizontal side slopes and a top width of 20 feet from the west abutment to Tonawanda Creek. From Tonawanda Creek to the east abutment, the top width is 10 feet. A 16-foot wide access road would be provided across the top of the upper embankment section with the 20-foot top width. This would allow maintenance access from State Route 98 to the control gates.

The abandoned Conrail railroad embankment was not considered for use in the plan of development as there is no available information as to its stability or content. In future studies, the railroad embankment would be investigated for possible use as a source of borrow material.

The foundation preparation would consist of clearing and grubbing, stripping and excavating for an inspection trench, riprap toes, and filter blanket. A preliminary underseepage analysis was performed and a positive cutoff is not considered necessary.

The impervious core will be built up to the top of the embankment with a filter zone to separate it from the pervious fill. On the downstream side of the core material, a filter blanket will extend out to the toe of the embankment. This filter will end in the toe for the riprap section.

Since the location of the flood control project is in the general vicinity of the Clarendon-Linden Fault, certain seismic design considerations were followed. These include the use of a thicker core of impervious material, graded filters in a zone located just downstream from the core, pervious downstream zones and cohesionless material upstream of the core. The correlation of the Standard Penetration Test and gradation of the foundation materials to the liquefaction potential of the material indicates that liquefaction may not be a problem. A detailed seismic analysis of both the dam and foundation material will be performed during the next phase of the project.

Riprap with a bedding layer would cover the exposed portion of the embankment. The riprap placed on the upstream face of the embankment will be 12 inches with a 6-inch bedding layer. This is necessary to protect it from wave action that might occur as a result of water ponding in the reservoir.

The top and downstream face of the embankment will be riprapped with 18-inch stone with a 6-inch bedding layer for use as an emergency spillway. The riprap will be chinked with 6 inches of topsoil and seeded with crown vetch. This is necessary to prevent migration of the riprap down the embankment slope due to the flow of water over the spillway. The velocity of the water over the spillway is relatively low, approximately 5 fps, thus 18-inch riprap should be satisfactory as noted in WES Report, T.R. 2-650 (see calculations in Section E7).

E5.3 Lower Reservoir Embankment

The lower embankment lies approximately one-half mile south of the city of Batavia (Plate E1). The total length of the embankment is approximately 5,600 feet. The embankment is designed to function as an emergency spillway with a top elevation of 900 feet from Creek Road westward for approximately 4,000 feet. From Creek Road to the east abutment, and for a short distance at the west abutment, the embankment is designed as a nonoverflow section with a top elevation of 905.5 and grassed slopes (Plates E4 and E7).

The embankment was developed with a one vertical to three horizontal side slope and a top width varying from 10 to 20 feet. The 20-foot wide top width section would extend from Creek Road west for approximately 800 feet to the control gates. This section would have a 16-foot wide access road to allow maintenance access to the gates from Creek Road.

The foundation preparation and construction of this embankment would be essentially the same as those for the upper reservoir embankment as discussed earlier.

E5.4 Underseepage Analysis

A preliminary underseepage analysis was performed for the Lower Reservoir. The Lower Reservoir was considered to be the more critical case since the foundation soils directly underlying the dam (gravelly sands) are considered to be more pervious than the foundation soils directly beneath the Upper Reservoir (sandy silts).

A presumptive value for permeability was determined based on the diameter of the foundation material which is 10 percent finer by weight (D_{10}). The permeability k, was presumed to be, $K = 8.20 \quad 10^{-5}$ ft/sec. for both the horizontal and vertical directions. This is based on an average D_{10} of .05 mm for the foundation material. From the preliminary underseepage analysis presented in Section E7, an exit gradient of 0.125 and a seepage velocity of 2.13×10^{-5} ft/sec. was determined. Exit gradients less than 1 are required to prevent piping from occurring in cohesionless soils. Due to the low exit gradients and seepage velocities, a positive cutoff is not considered necessary. In-situ soil permeability wil be determined in the next phase so that a more exact underseepage analysis can be performed.

E5.5 Training Dikes

Nonoverflow training dikes are proposed for both the east and west sides of the Tonawanda Creek Valley. The total length of these embankments is approximately 5,030 feet (see Plate E1).

The foundation preparation and construction of the dikes is essentially the same as those for the upper and lower embankments. The noticeable difference in the dikes is the side slopes are grassed rather than riprapped as the embankments are designed as nonoverflow sections (see Plate E8).

E5.6 Further Studies

Additional subsurface investigations will be performed for the final design, Phase II GDM. These will include obtaining undisturbed and disturbed samples and possibly "Dutch Cone" penetrometer tests to determine, with a great degree of confidence, the liquefaction potential of the soil. Field pumping tests to determine the permeability of the soil and a general comprehensive investigation to determine the locations of buried channels and location of required materials will also be performed.

E6. MATERIALS SURVEY

The construction materials required to build the embankments are:

riprap
riprap bedding material
transition zone and filter material
impervious fill
pervious fill
concrete aggregates

These materials would be used as shown in the cross sections that appear on Plates E3 and E4. A paper materials survey was prepared for the required quarried materials and appears on Plate E5.

The impervious fill consisting of soil with high clay and silt content will form the core of the dam. A review of the surficial geology of the area indicates that suitable impervious material may be found within 15 miles of the project site. Test pits and borings will be utilized to identify sources available for this purpose.

Pervious fill will be utilized to fill in the remainder of the cross section. It will consist of gravel and sand with some silt and clay. The material will have varying amounts of different size particles. The only requirements for the material is that it be free of spoil (that is, cinders, bricks, garbage, and other such material), organic material, and have a maximum size of 6 inches.

The pervious fill will also be utilized to form a bedding layer under the principal outlet works. This will consist of granular material having a maximum size of 3 inches. Material suitable for this purpose is available near the project site.

The stone for the riprap, filter, bedding, and transition materials is available from nine quarry operations within 30 miles of Batavia.

Coarse aggregate for concrete is available from five sources within 30 miles of Batavia. In addition, fine aggregate is available from two sources within 30 miles of Batavia.

The disposal of spoil materials from stripping, clearing and grubbing, and excavation will be accomplished by their removal to landfills or by burial at the project site.

E7. CALCULATIONS

Subject: Tonawanda Creek F.C.P

Computation of: Riprap for wave action

Computed by: JAG Checked by: Date: 6/28/79

From EM 1110-2-2300, Fig 5-5:

Assumed Wave height = 2 ft

Sp Gr Stone = 2.5

From EM 1110-2-2300, Fig 5-6

with side slopes 1V:3H

wave height = 4 ft

Sp gr Stone = 2.5

Riprap req'd = 12"

Subject Tonawanda Creek F.C.P

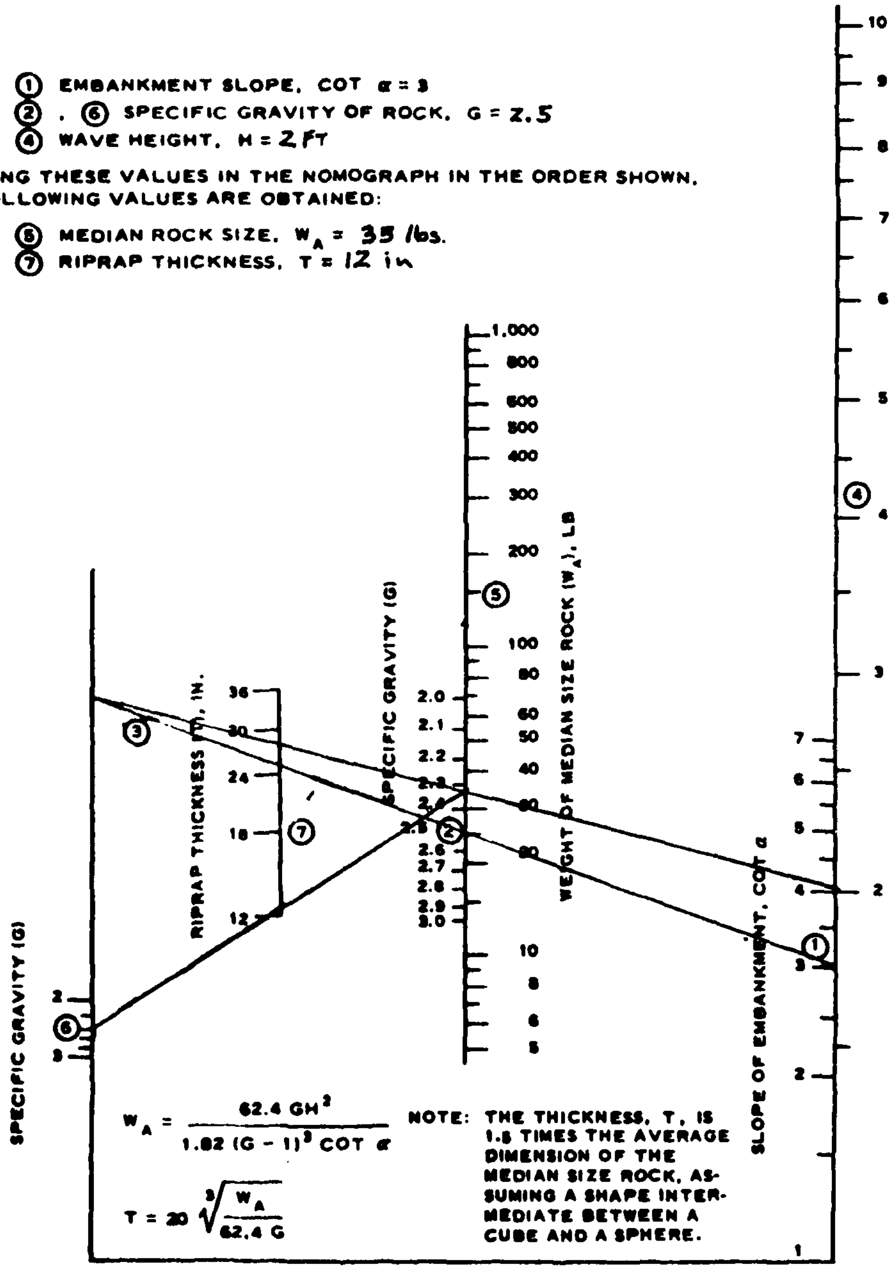
Computation of Riprap for wave action

Computed by JAG Checked by ______ Date 6/28/79

GIVEN: (1) EMBANKMENT SLOPE, COT α = 3
(2), (6) SPECIFIC GRAVITY OF ROCK, G = 2.5
(4) WAVE HEIGHT, H = 2 FT

ENTERING THESE VALUES IN THE NOMOGRAPH IN THE ORDER SHOWN, THE FOLLOWING VALUES ARE OBTAINED:

(5) MEDIAN ROCK SIZE, W_A = 35 lbs.
(7) RIPRAP THICKNESS, T = 12 in



$$W_A = \frac{62.4\ GH^3}{1.82\ (G-1)^3\ \cot\alpha}$$

$$T = 20\ \sqrt[3]{\frac{W_A}{62.4\ G}}$$

NOTE: THE THICKNESS, T, IS 1.5 TIMES THE AVERAGE DIMENSION OF THE MEDIAN SIZE ROCK, ASSUMING A SHAPE INTERMEDIATE BETWEEN A CUBE AND A SPHERE.

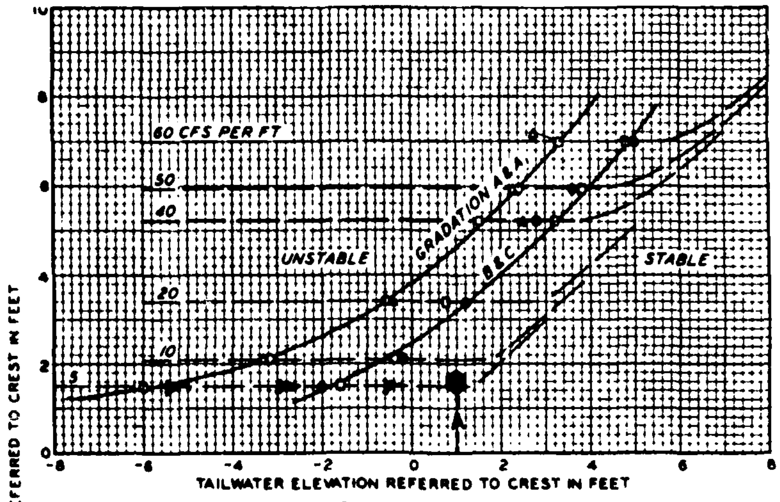
Slope protection nomograph for dumped riprap for earth dams

Page ____ of ____ pages

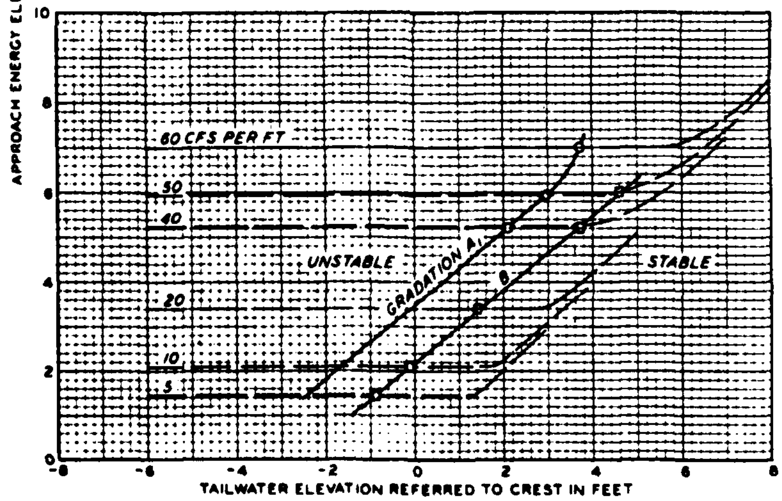
Subject Tonawanda Creek F.C.P

Computation of Riprap for overflow

Computed by JAG **Checked by** ______________ **Date** 9/4/80



TEST SERIES 1 (10-FT-HIGH EMBANKMENT)



TEST SERIES 4 (3-FT-HIGH EMBANKMENT)

Given: 10 ft High Embankment
velocity ≈ 5 fps
Use Test Series 1
Assume Tailwater Elevation 1' above crest
∴ ok to use 18" riprap

LEGEND

SYMBOL	GRADATION
○	A₁ – 24" max
△	A – 36" max
□	B – 16" max
●	C – 24" max

LIMITS OF STABILITY
ACCESS TYPE EMBANKMENTS
From TR. No 2-650

Subject Tonawanda Creek F.C.P
Computation of Seepage Analysis
Computed by JAG Checked by ______ Date -/19-

Assume: Low dam treated as a levee, no flow thru embankment & $K_h = K_v$

Given: H = head H_2O = 10 ft
K = permeability $= CD_{10}^2$
where $C = 100$
$D_{10} = .05$ mm - from grad test
$K = .0025$ cm/sec $= 8.2 \times 10^{-5}$ ft/sec
d = depth pervious layer = 20 ft
L_2 = length seepage under dam = 80 ft

CASE I EM-1110-2-1913

No Top Stratum

$$\$ = \frac{d}{L_2 + .86d}$$

$\$ = .206$ = shape factor $= \frac{n_f}{n_d}$ (Flow lines) / (equipotential lines)

$Q = \$ KH$

$Q = .206(8.2 \times 10^{-5}$ ft/sec$) \, 10$ ft

$Q = 1.68 \times 10^{-4}$ CFS - very low flow

Determine Exit Gradient i (See flow net diagram)

$$i = \frac{\Delta h}{l}$$

where $\Delta h = H/n_d$

$\Delta h = 10/20$

$\Delta h = .5$

Subject: Tonawanda Creek FCP
Computation of: Seepage Analysis
Computed by: JAG Checked by: Date: 3/10/78

l = length of seepage path @ exit

$l \approx 4$ ft

$i = .5/4$

$i = .125 < 3$ OK

Where 3 is the critical value for cohesionless soils - from Intro. Soil Mech & Foundations, Sowers

Seepage Velocity V_s

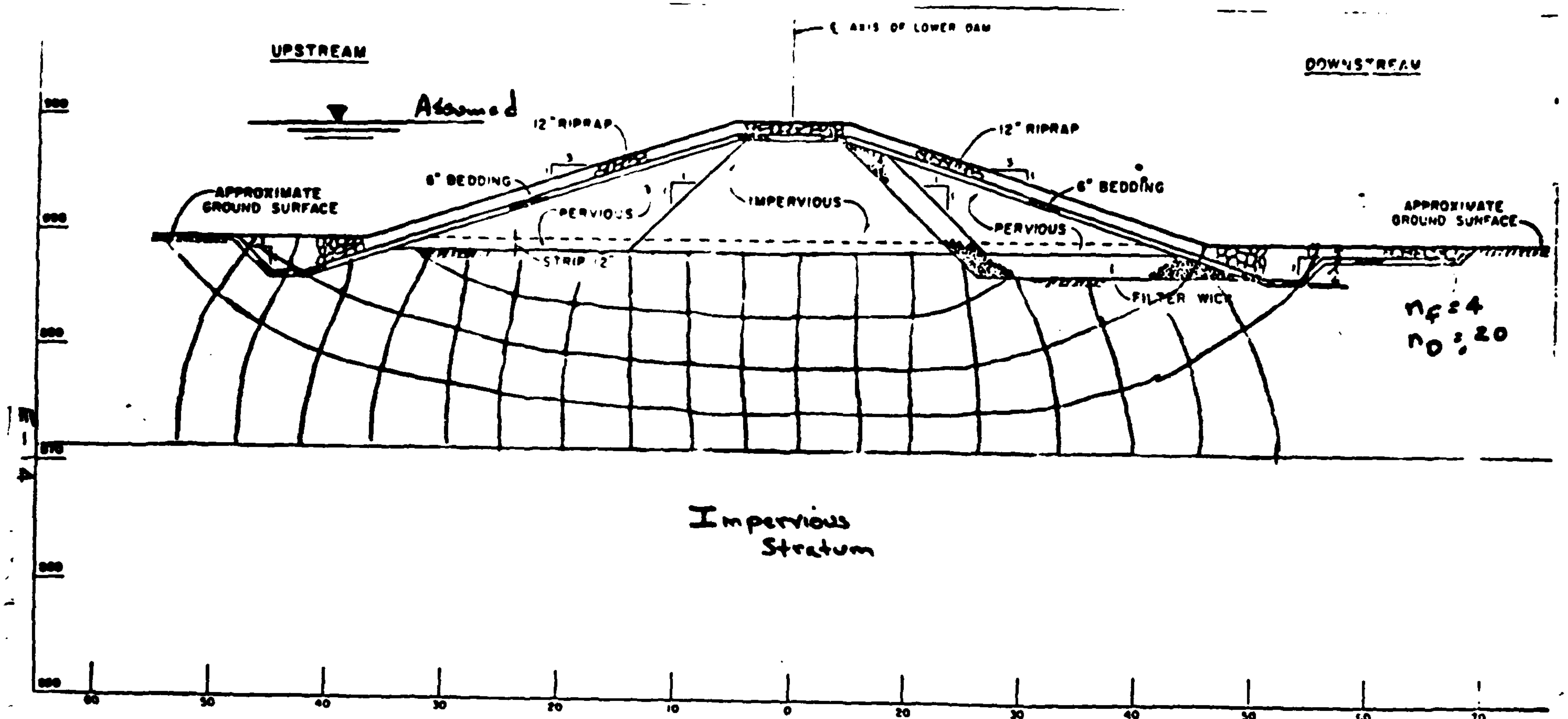
$V_s = \frac{Ki}{n}$ (from Soil Mechanics Lambe & Whitman)

n = porosity = .48 for loose sand (from Basic Soils Eng. B K Hough)

$$V_s = \frac{(8.2 \times 10^{-5} ft/sec)(.125)}{.48}$$

$$V_s = 2.13 \times 10^{-5} ft/sec$$

Conclusion: Due to the low exit gradient & seepage velocity, boiling is not likely to occur & a slurry cut off is not required.



Geologic Section A-A DISTANCE IN FEET

Seepage Analysis - Flow Net Diagram
Lower Reservoir

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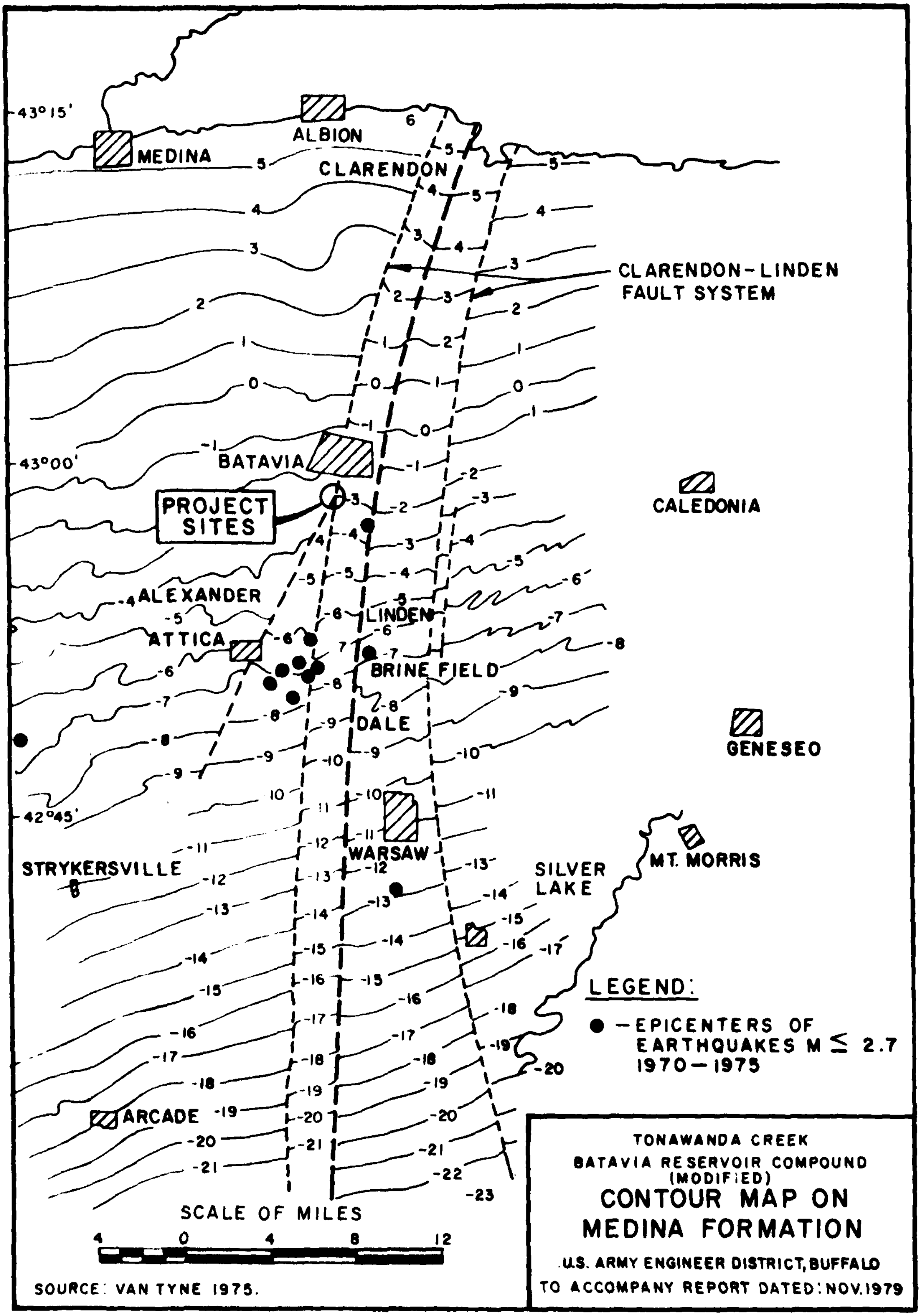
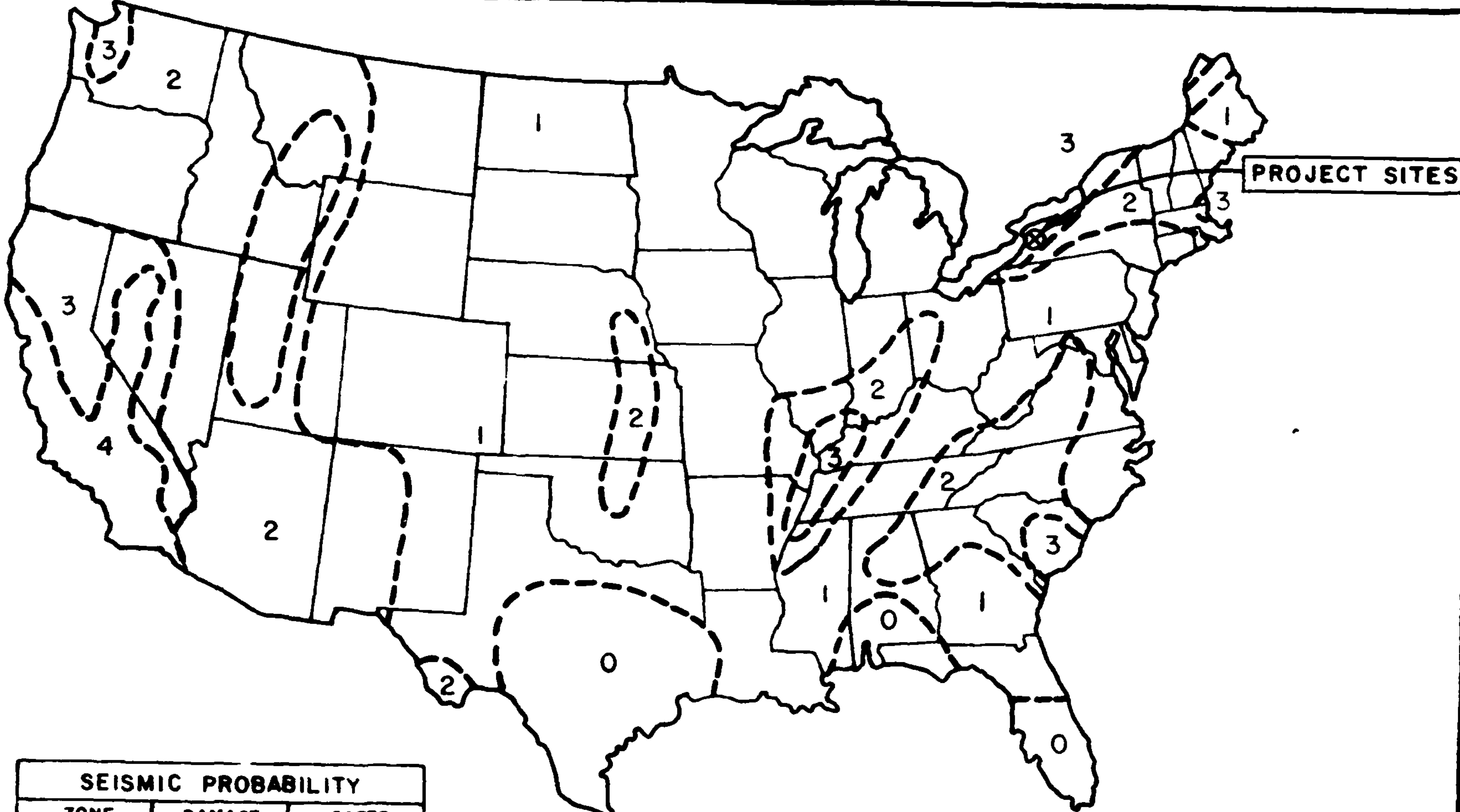

43°15'
43°00'
42°45'
MEDINA
ALBION
CLARENDON
CLARENDON-LINDEN
FAULT SYSTEM
BATAVIA
PROJECT
SITES
CALEDONIA
ALEXANDER
ATTICA
LINDEN
BRINE FIELD
DALE
GENESEO
WARSAW
STRYKERSVILLE
SILVER
LAKE
MT. MORRIS
ARCADE
LEGEND:
● — EPICENTERS OF
EARTHQUAKES M ≤ 2.7
1970 — 1975
SCALE OF MILES
4 0 4 8 12
SOURCE: VAN TYNE 1975.
TONAWANDA CREEK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)
CONTOUR MAP ON
MEDINA FORMATION
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: NOV. 1979

FIGURE E1



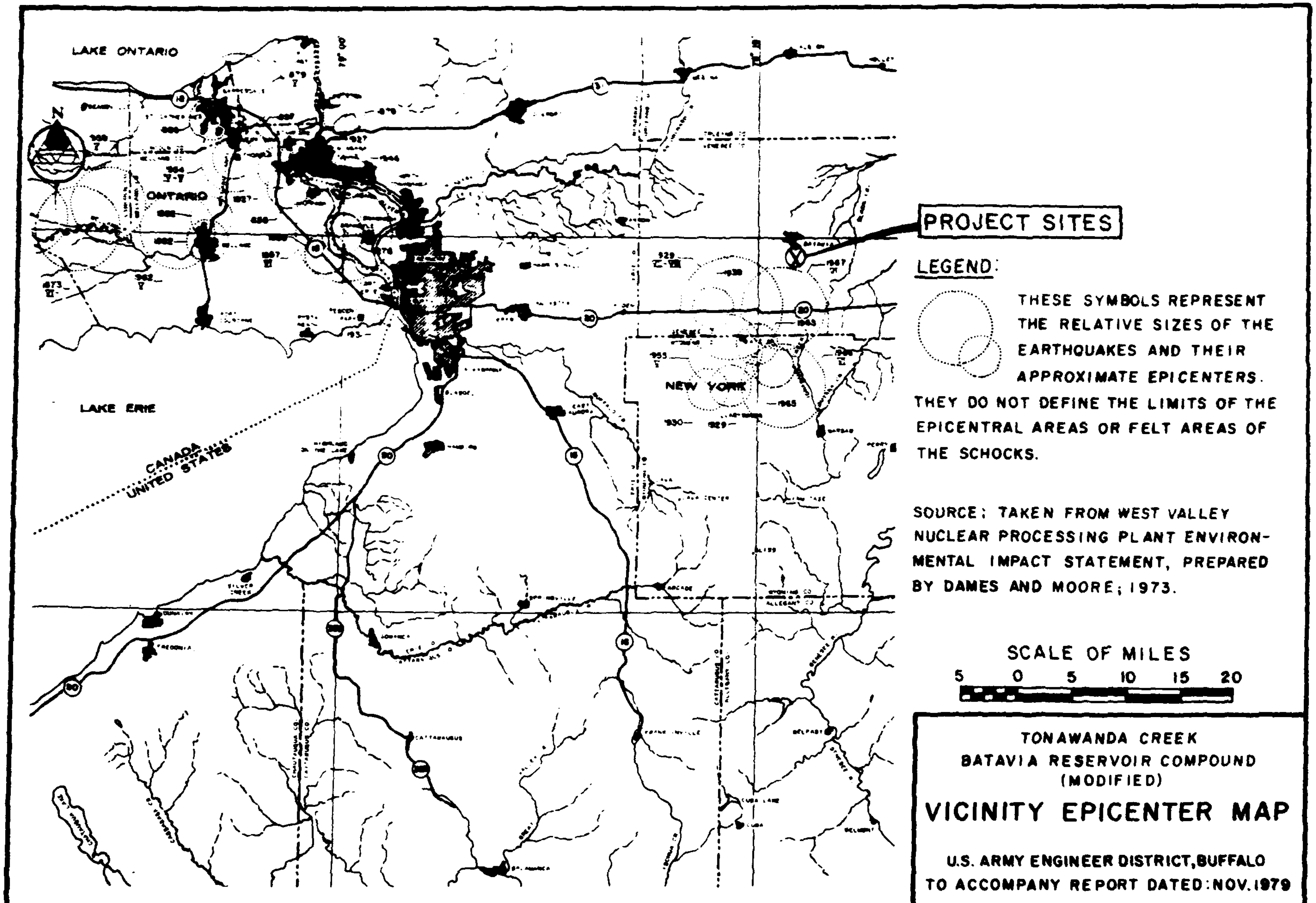
SEISMIC PROBABILITY		
ZONE	DAMAGE	COEFF.
0	NONE	0
1	MINOR	0.025
2	MODERATE	0.05
3	MAJOR	0.10
4	GREAT	0.15

TONAWANDA CREEK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

SEISMIC RISK ZONES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED NOV. 1979

FIGURE E2

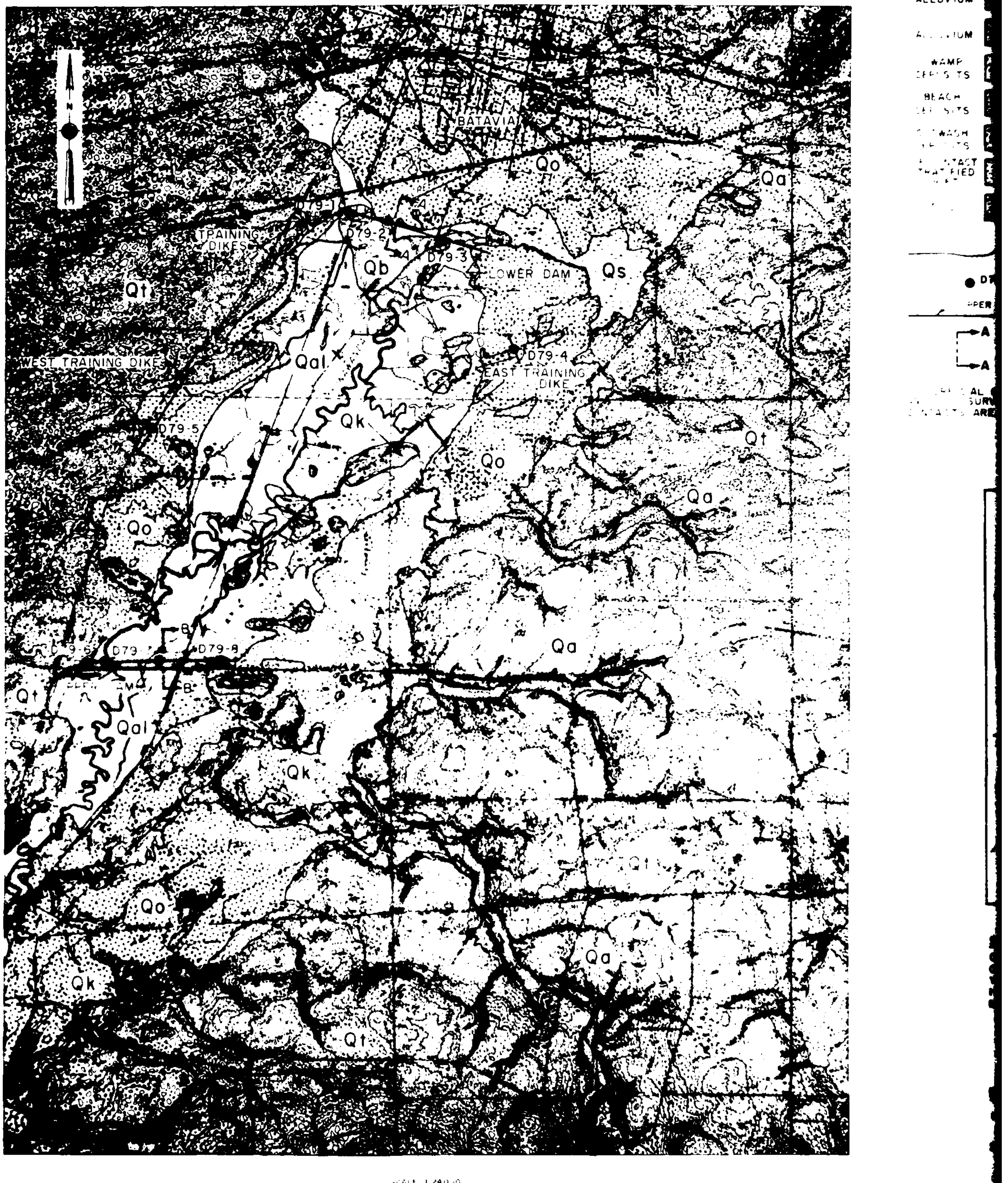


TONAWANDA CREEK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

VICINITY EPICENTER MAP

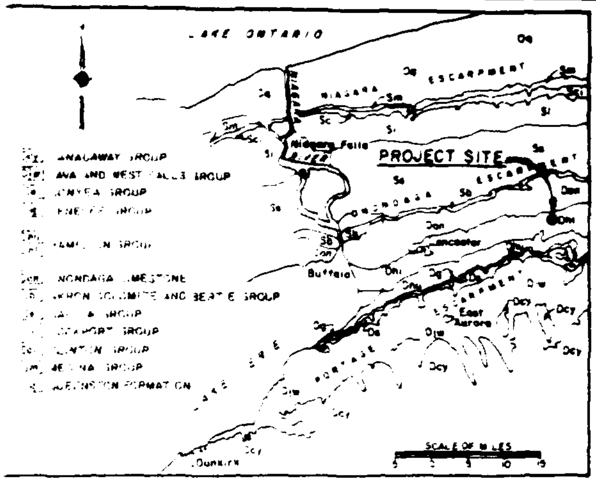
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: NOV. 1979

FIGURE E3



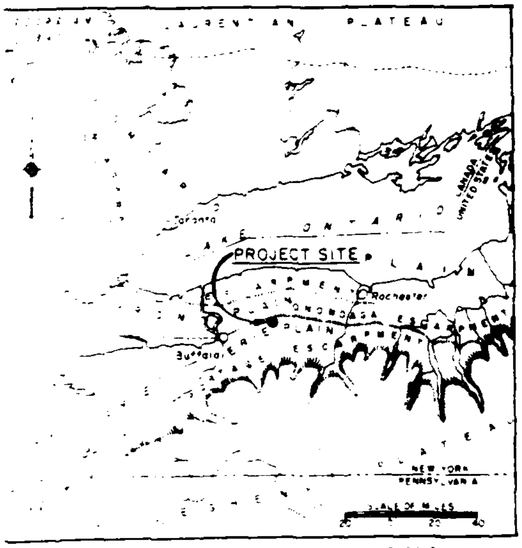
LOCAL SURFICIAL GEOLOGY

LEGEND



BEDROCK GEOLOGY OF NORTHWESTERN NEW YORK

SOURCE:
CALKIN, PARKER E., 1966, LATE PLEISTOCENE HISTORY OF NORTHWESTERN NEW YORK IN GUIDEBOOK, GEOLOGY OF WESTERN NEW YORK, NEW YORK STATE GEOLOGY ASSOCIATION, 38TH ANNUAL MEETING, 1966



SKETCH MAP OF PHYSIOGRAPHIC DIVISIONS IN THE LAKE ONTARIO-LAKE ERIE REGION

SOURCE:
KINDLE, E. M. AND TAYLOR, F. B., 1913, DESCRIPTION OF THE NIAGARA QUADRANGLE (N.Y.) U.S. GEOL. SURVEY GEOL. ATLAS, FOLIO 190

NOTES:

TONAWANDA CREEK WATERSHED, NEW YORK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

SURFICIAL AND REGIONAL GEOLOGY

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: NOV. 1980

PLATE E1

BORING NO	SAMPLE NO	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %		ATTERBERG LIMITS		
D79-1	1	0 -1.5	OL	1	46	53		25 0	31 5	
	5	4.5 -6 0	GM	15	50	35				
	6	6 0'-7 5'	SW	35	40	25				
	7	7 5'-8.5'	SW	35	50	15		16 8	18.5	
	9	10 5'-12'	GW	43	40	17				
	10	10.5'-11 5	SW	27	53	20				
D79-2	2	1.5'-3 0'	SM	0	62	38			NP	
	4	3.5'-4 5'	SW	0	95	5	09MM		NP	
	5	4.5'-6 0'	SW	5	78	17			NP	
	8	7.5'-9 0'	SP	3	78	19			NP	
	11	12'-13.5'	SP	2	76	22			NP	
D79-3	3&4*	3.0'-6.0'	SP	4	73	23			NP	
	5&6*	6.0'-7 5'	SP	2	81	17			NP	
	7	7.5'-9.0'	SP	13	70	17			NP	
	10	10 5'-11.2'	SW	24	68	8	0.1MM		NP	
	12* &	12'-15	SP	1	85	14			NP	
	13*	12'-15'	SP	1	85	14			NP	
	14* &	15'-17 2'	SP	1	85	14			NP	
	15*	15'-17 2'	SP	1	85	14			NP	
	16	17 2'-18'	ML	0	22	78			NP	
	17	18'-19 5'	SP	0	87	13			NP	
	19	20 2 -21'	ML	11	16	73		14.8	16.3	
D79-4	2	1.5'-3 0'	GP	94	5	1				
	5	6.0'-7 5'	GW	42	30	28				5.6
	7	9 -10.5'	GW	56	44	0				
	11	13.5 15'	SM	30	35	35		16.5	18.6	12.3
	15	18 -19.5'	SW	40	38	22		17.5	20.1	
	18	21 -22.5'	GP	20	47	33				
	20	24'-25.5'	GW	34	43	23				10.6
D79-5	2	2 0'-3 5'	SP	0	70	30				
	3	3.5'-5.0'	ML	2	4	94			NP	19 4
	4	5 0'-6 5'	GW	37	45	18				
	5	6.5'-8.0'	GM	16	32	52				
	6	8 0'-9 5'	GM	32	48	20			NP	7.5
	7	9 5'-11'	GW	22	42	36				7.5
	8	11 -12.5'	GW	48	34	18				6.4
	9	12 5'-14'	GW	26	46	28				8 0
D79-6	1	0-1.5	OH	0	8	92		34.8	48 5	
	3	3 -4 5	OH	0	24	76		25.7	34.1	29.0
	4	4 5 -6 0'	MH	0	1	99		32 4	51.1	25 0

TEST DATA SUMMARY

BATAVIA RESERVOIR COMPOUND (MODIFIED)

TRIAXIAL COMPRESSION

UNCONFINED COMPRESSION

NP - NON PLASTIC

DS DIR

U UNC

* - COM

SHEET 1 OF 2

DIRECT SHEAR
UNCONSOLIDATED UNDRAINED
CONSOLIDATED DRAINED
R CONSOLIDATED UNDRAINED

- COMPOSITE SAMPLE

BORING NO	SAM NO	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY	NAT WATER CONT %	NATURAL DRY DENSITY
	7	9 -10.5	GM	14	34	52			NP		18.3	
	8	10.5 -12	ML	0	2	98		17.6	21.9		14.1	
D79-6	9	12 -13.5	ML	3	5	92		15.8	17.7		13.0	
	10	13.5 -15'	ML	0	4	96		18.1	22.6			
	11	15 -16.5'	ML	0	4	96		17.5	23.3		12.7	
	13	18'-19.5'	ML	0	6	94		16.5	18.1			
	16	22.5 -24	ML	12	28	60		13.2	16.3		11.8	
	17	24'-25.5'	GM	12	42	46						
D79-7	1	0'-1.5	MH	2	8	90		30.7	40.5			
	3	3'-4.5	MH	0	1	99		29.1	45.9			
	4	4.5 -6	CL	0	2	98		31.7	47.6		31.2	
	6	7.5 -9	ML	0	8	92		20.6	28.2			
	7	9 -10.5	ML	0	4	96		20.0	26.7			
	8	10.5 -12'	ML	0	24	76						
	9	12'-13.5'	MH	0	1	99		21.2	25.4		31.6	
	11	15'-16.5	SW	1	93	6	.2MM					
	13	18.5 -20'	GW	40	53	7	.12MM					
	14	20'-21.5'	ML	1	1	98		18.1	25.2		18.7	
	15	21.5 -23'	ML	0	3	97		17.1	21.3			
	16	23'-24.5'	ML	0	1	99		16.1	20.3		17.8	
	18	26'-27.5'	ML	0	1	99		17.9	24.0		22.1	
	20	29'-30.5'	ML	0	0	100		17.6	22.9			
	23	33.5 -35'	ML	0	2	98		15.5	20.6		20.4	
	24	35'-36.5'	ML	0	2	98		17.7	24.6			
	26	38'-39.5'	CL - ML	0	5	95		16.1	20.4			
	31	45.5 -47'	ML	0	17	83		14.8	18.4		16.7	
	32	47'-48.5'	ML	0	34	66						
	34	50'-51.5'	ML	2	30	68		14.1	14.5			
	37	54 5'-56'	GW	40	47	13						
D79-8	1	0'-1.5	SC - OL	8	54	38						
	2	1.5 -3.0'	SW	23	59	18						
	4	4.5'-6'	GP	48	40	12						
	7	9 -10.5'	SW	19	65	16					12.4	
	8	10.5'-12	GW	30	60	10						
	12	15'-16.5'	CL - ML	3	5	92		18.4	24.7			
	16	21'-22.5'	ML	0	1	99		16.9	23.0		22.3	
	19	25.5'-27'	CL - ML	0	2	98		17.8	24.6			

TEST DATA SUMMARY

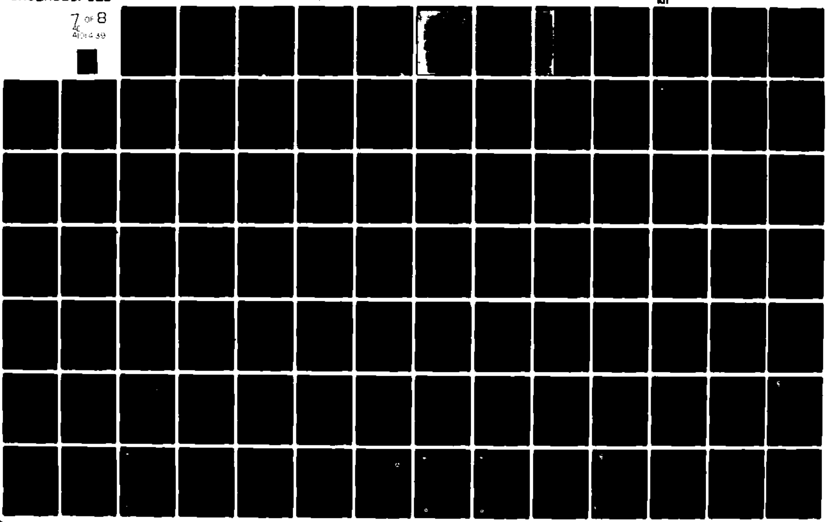
PROJECT BATAVIA RESERVOIR COMPOUND (MODIFIED)

INITIAL	DRY DENSITY (LBS/CU FT)					SHEAR DATA TYPE TEST	SPECIMEN SIZE (INCHES)		T/SQ FT		T/SQ FT	DEGREES	PERMEABILITY

AD-A101 439 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2
BUFFALO METROPOLITAN AREA, NEW YORK WATER RESOURCES MANAGEMENT --ETC(U)
1980

UNCLASSIFIED NL

AD A101439



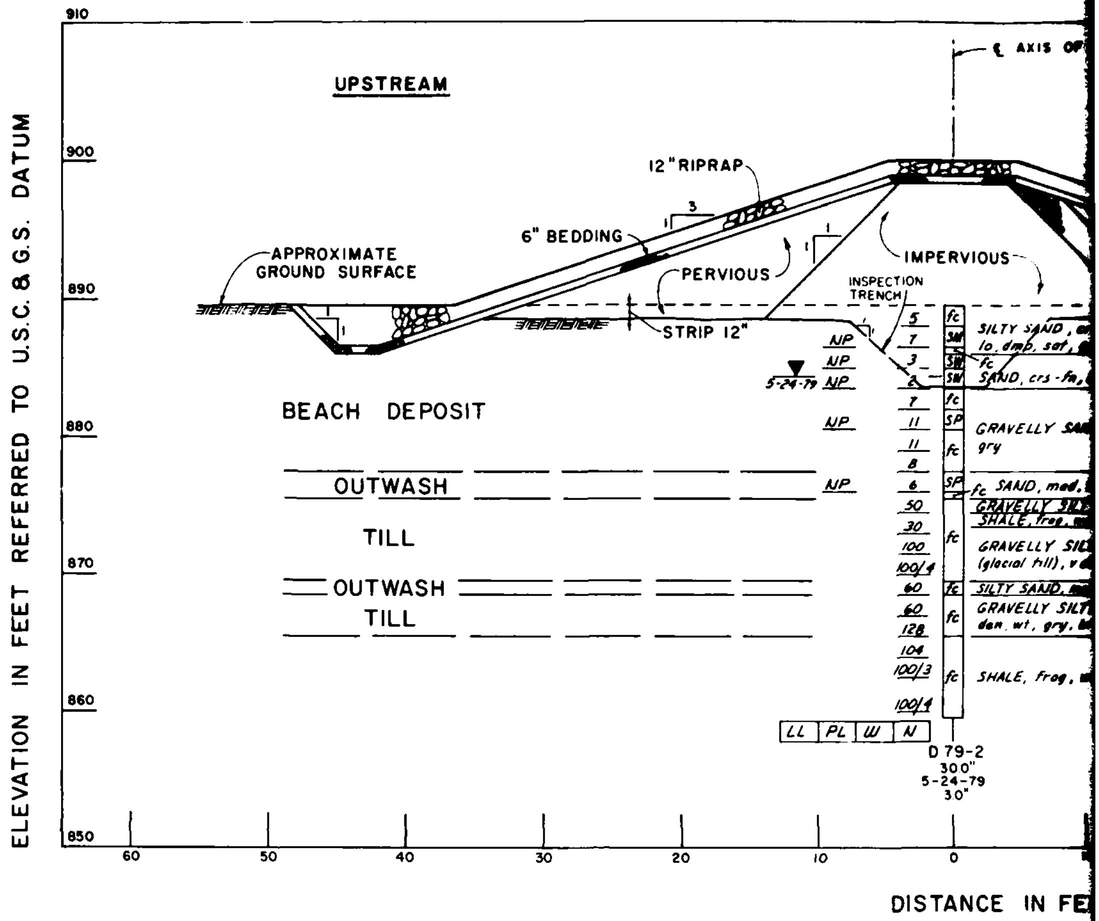
SHEET 2 OF 2

ABILITY	CONSOLIDATION DATA				REMARKS
k FT/MIN	P_O T/SQ FT	P_C T/SQ FT	C_C	t_{50}	

ECT SHEAR
CONSOLIDATED UNDRAINED

S - CONSOLIDATED DRAINED
R CONSOLIDATED UNDRAINED

PLATE E2



GEOLOGIC SECTIO

LEGEND FOR BORINGS

Hole number and designation — D 79-2
Drive sample
Year of boring
Boring number

| PL | LL | W | N |

Elevation and date water level observed — 5-24-79
Standard penetration test (Blows/Ft) — 12
Water content-percent (W) — 44.1
Liquid limit (LL) — 52
Plastic limit (PL) — 23
Dividing line between classifications
Unified soil classification determined in laboratory
Field classification
Total depth of exploration — 63.7
Drilling completion date — 9-30-77
Diameter of sample — 3.0' soils

Material classification from visual and laboratory descriptions as appropriate
CL
SM
SP — *SAND, med, lo, dmp, gry*
CH — *CLAY, tr f sd, so-med, brn*
CL
fc — *SANDY CLAY, hd, dmp, brn*

TERMS FOR RELATIVE DENSITY AND CONSISTENCY

BASIC SOIL TYPE	RELATIVE DENSITY OR CONSISTENCY	RANGE OF STANDARD PENETRATION RESISTANCE (1)
SAND AND SILT	VERY LOOSE	LESS THAN 5 PER FOOT
	LOOSE	5 TO 17
	MEDIUM DENSE	17 TO 45
	DENSE	45 TO 70
	VERY DENSE	GREATER THAN 70
CLAY	VERY SOFT	LESS THAN 2 PER FOOT
	SOFT	2 TO 4
	MEDIUM STIFF	4 TO 8
	STIFF	8 TO 18
	VERY STIFF	18 TO 35
	HARD	GREATER THAN 35

(1) NUMBER OF BLOWS FROM 375-LB WEIGHT FREE FALLING 18 INCHES TO DRIVE A 3.5 INCH OD SAMPLER ONE FOOT.

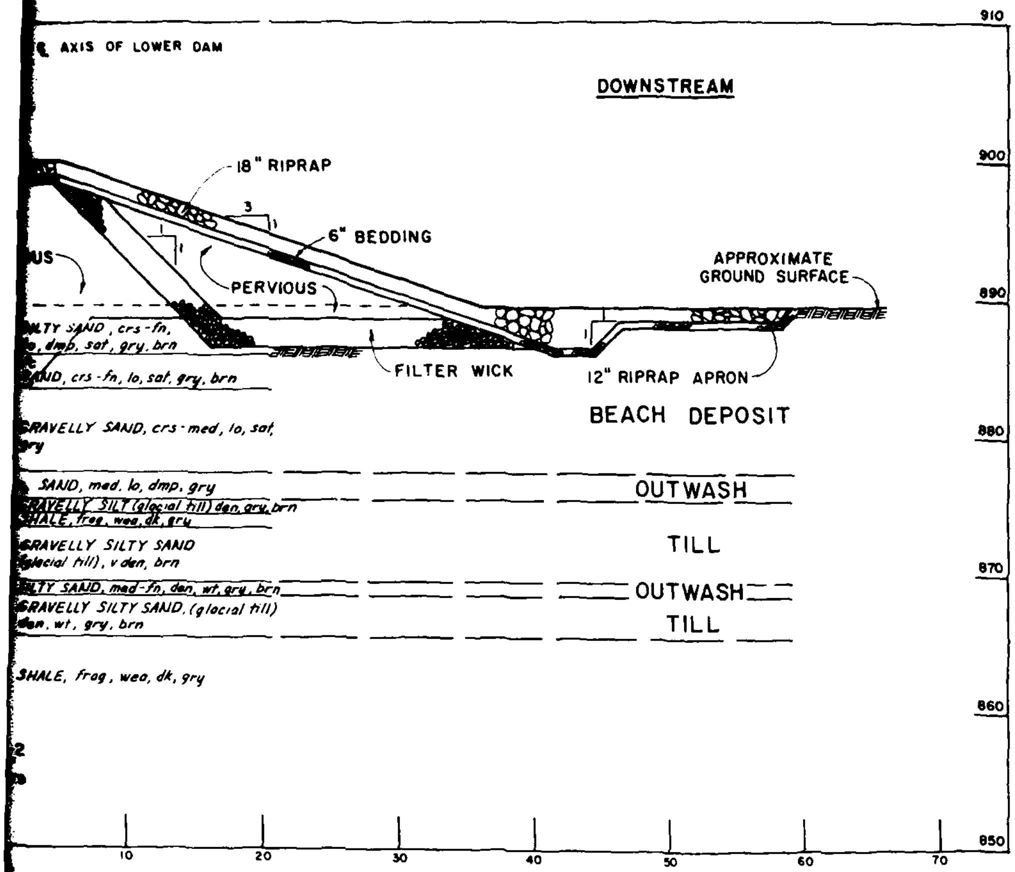
AB

ang angular
brk broken
DDM
frag fragmented

NOTES:

1 FOR LOCATION OF SECT
2 FOR DESCRIPTION OF
3 FOR OTHER GEOLOGIC

1



...CE IN FEET

...SECTION A-A

ABBREVIATIONS

...lar	gr	gravel	rts	roots
...llaceous	gr	granular	rk	rock
...en by ...	gry	gray	sat	saturated
...	ha	high angle	se	seams
...ch	hd	hard	sd(y)	sand(y)
...n	h	horizontal	sh(y)	shale(y)
...ken	[illegible]	joint	si(y)	silt(y)
...ks	la	low angle	sil s	siliceous
...careous	[illegible]	little	so	soft
...e	ls	limestone	som	some
...rse	[illegible]	light	st	stained
...rt	lo	loose	stf	stiff
...y (ey)	L.C.	lost core	sty	stylolitic
...k	med	medium	sub	subangular
...p	mst	moist	tht	throughout
...se	mt	material	tr	trace
...	nd	nodules	thk	thick
...ular Onondaga	NP	Non Plastic	th	thin
...e	num	numerous	v	very
...il	o	open	vert	vertical
...cture	org	organic	w	water
...mented	[illegible]	plastic	w	with
...in	ptg(s)	partings	wea	weathered
	r	round	wt	wet

...:
...ATION OF SECTION - SEE PLATE E1
...CRIPTION OF GEOLOGIC UNITS - SEE PLATE E1
...ER GEOLOGIC SECTION - SEE PLATE E4

LEGEND (UNIFIED SOIL CLASSIFICATION SYSTEM)

GW	WELL GRADED GRAVELS, GRAVEL SAND MIXTURES, LITTLE OR NO FINES.	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
GP	POORLY GRADED GRAVELS OR GRAVEL SAND MIXTURES, LITTLE OR NO FINES.	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS.
GM	SILTY GRAVELS, GRAVEL SAND SILT MIXTURES	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY.
GC	CLAYEY GRAVELS, GRAVEL SAND CLAY MIXTURES	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS.
SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS.
SP	POORLY GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES.	OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS.
SM	SILTY SANDS SAND SILT MIXTURES.	PT	PEAT AND OTHER HIGHLY ORGANIC SOILS.
SC	CLAYEY SANDS, SAND CLAY MIXTURES.		

CLASSIFICATION FROM ACTUAL LABORATORY TESTS WHERE LL AND PL ARE SHOWN.

DUAL CLASSIFICATION, WHERE USED IS IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

FOR DETAILS ON THE UNIFIED SOIL CLASSIFICATION SYSTEM, SEE WATERWAYS EXPERIMENT STATION TECHNICAL MEMORANDUM NO. 3-357 DATED MARCH 1953 AND REVISED IN 1960.

TONAWANDA CREEK WATERSHED, NEW YORK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

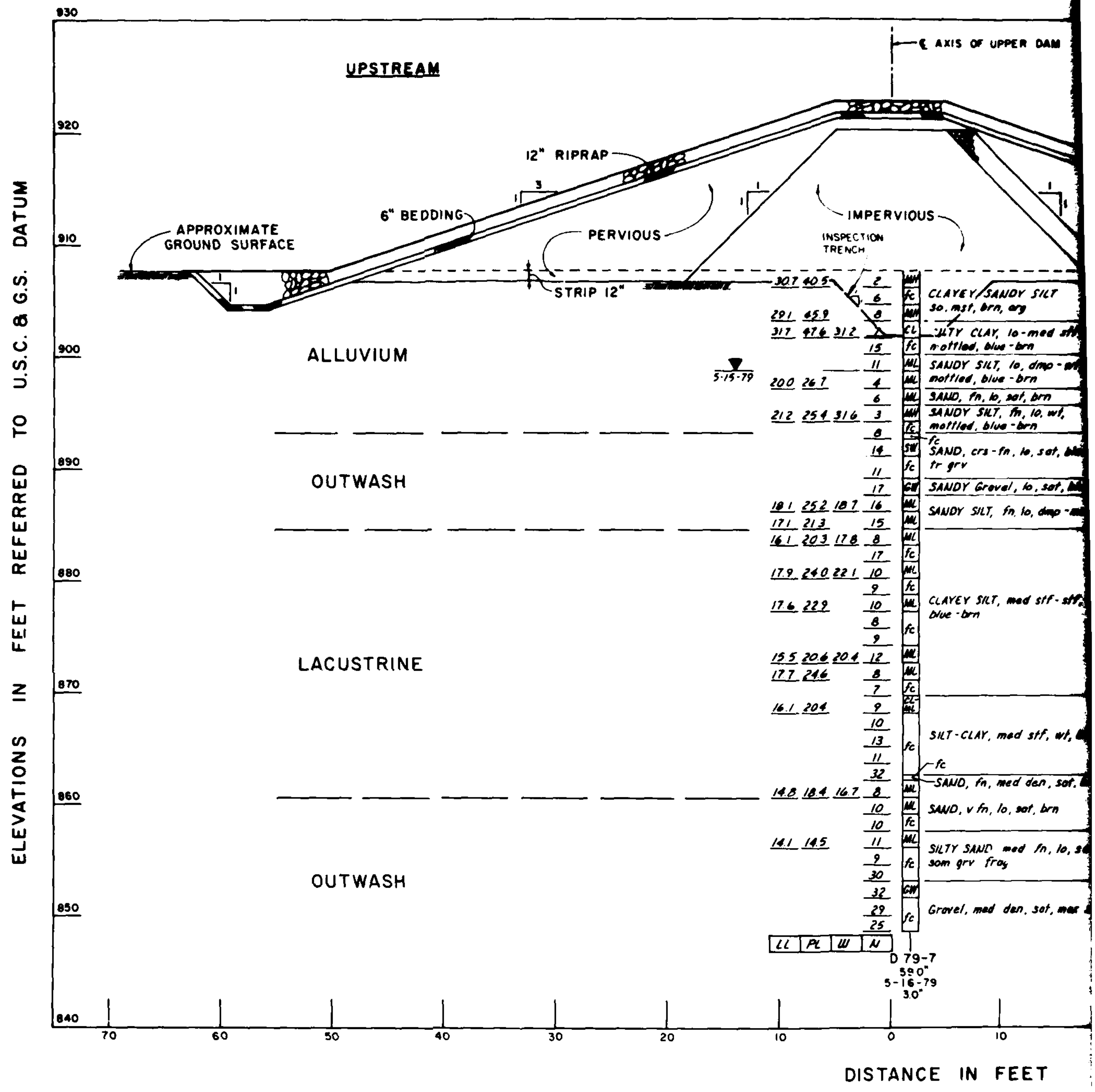
GEOLOGIC SECTION A-A
LOWER DAM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: NOV. 1980

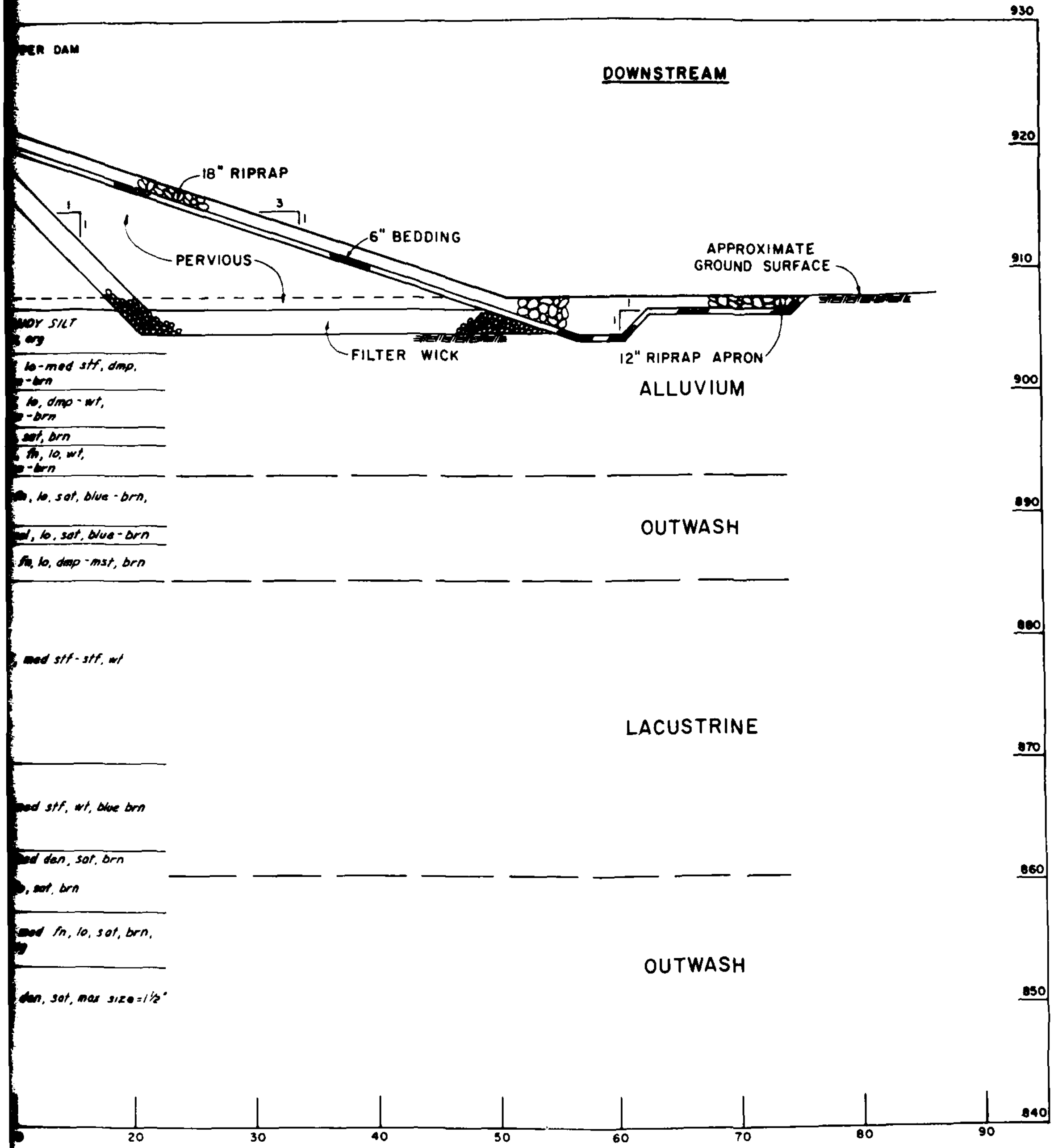
PLATE E3

1

2



GEOLOGIC SECTION B-



FEET

ON B-B

NOTES:

1 FOR LOCATION OF SECTION – SEE PLATE E1
2 FOR DESCRIPTION OF GEOLOGIC UNITS – SEE PLATE E1.
3 FOR LEGEND FOR BORINGS AND ABBREVIATIONS – SEE PLATE E3
4 FOR OTHER GEOLOGIC SECTION SEE PLATE E3

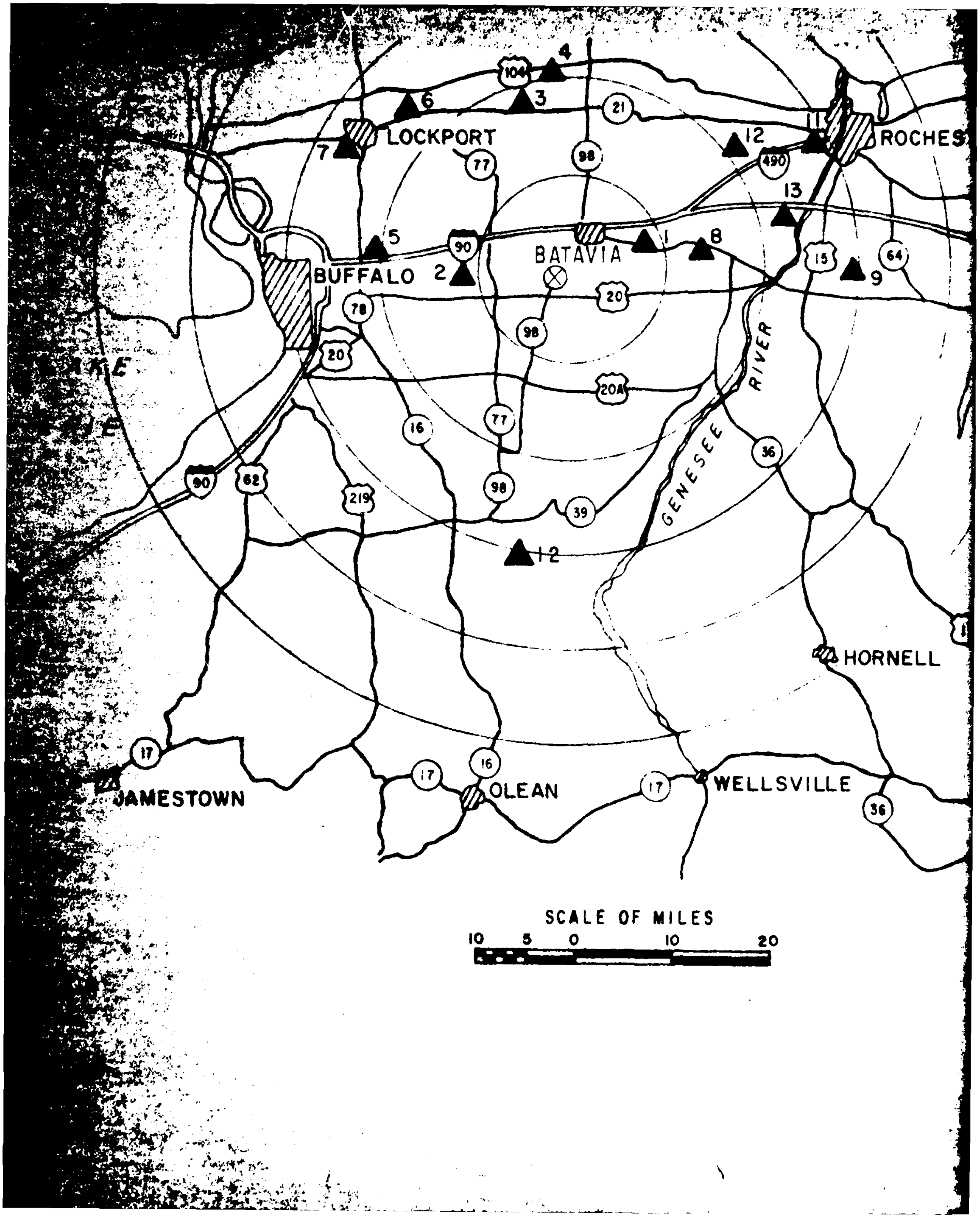
TONAWANDA CREEK WATERSHED, NEW YORK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

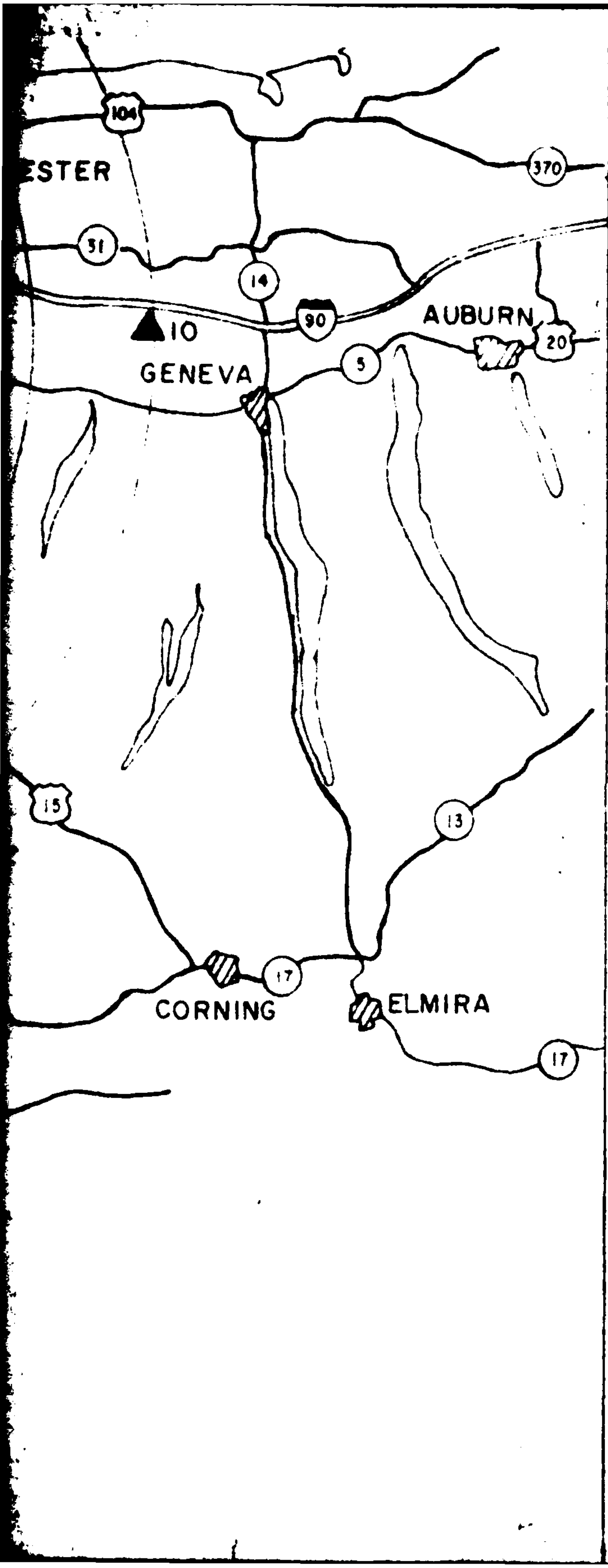
GEOLOGIC SECTION D-D
UPPER DAM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: NOV. 1980

PLATE

1 2


LOCKPORT
ROCHES
BUFFALO
BATAVIA
GENESEE RIVER
HORNELL
JAMESTOWN
OLEAN
WELLSVILLE
SCALE OF MILES
10 5 0 10 20



SITE NO.	SOURCE AND ADDRESS	
1.	GENESEE STONE PRODUCTS CO. QUARRY AT STAFFORD, N.Y.	RI CO
2.	COUNTY LINE STONE CO. QUARRY AT AKRON, N.Y.	RI
3.	MEDINA SANDSTONE CO. QUARRY AT MEDINA, N.Y.	RI
4.	B.R. DEWITT PIT AT OAK ORCHARD, N.Y.	FI
5.	HOUDAILLE CONSTRUCTION MAT'S QUARRY AT LANCASTER, N.Y.	RI
6.	ROYALTON STONE PRODUCTS, INC. QUARRY AT GASPORT, N.Y.	RI
7.	FRONTIER STONE PRODUCTS, INC. QUARRY AT LOCKPORT, N.Y.	RI CO
8.	GENERAL CRUSHED STONE, CO. QUARRY AT LEROY, N.Y.	RI
9.	GENERAL CRUSHED STONE, CO. QUARRY AT HONEOYE FALLS, N.Y.	RI
10.	CONCRETE MATERIALS, INC. QUARRY AT MANCHESTER, N.Y.	BE CO
11.	DOLOMITE PRODUCTS, INC. QUARRY AT GATES CENTER, N.Y.	RI CO
12.	SPENCER AND HALEY INC PIT AT DELEVAN, N.Y.	FI CO

▲ QUARRY OR PIT LOCATION

⊗ PROJECT SITES

TONAWANDA C

BATAVIA RES

(M

POSSIBLE

U.S. ARMY ENG

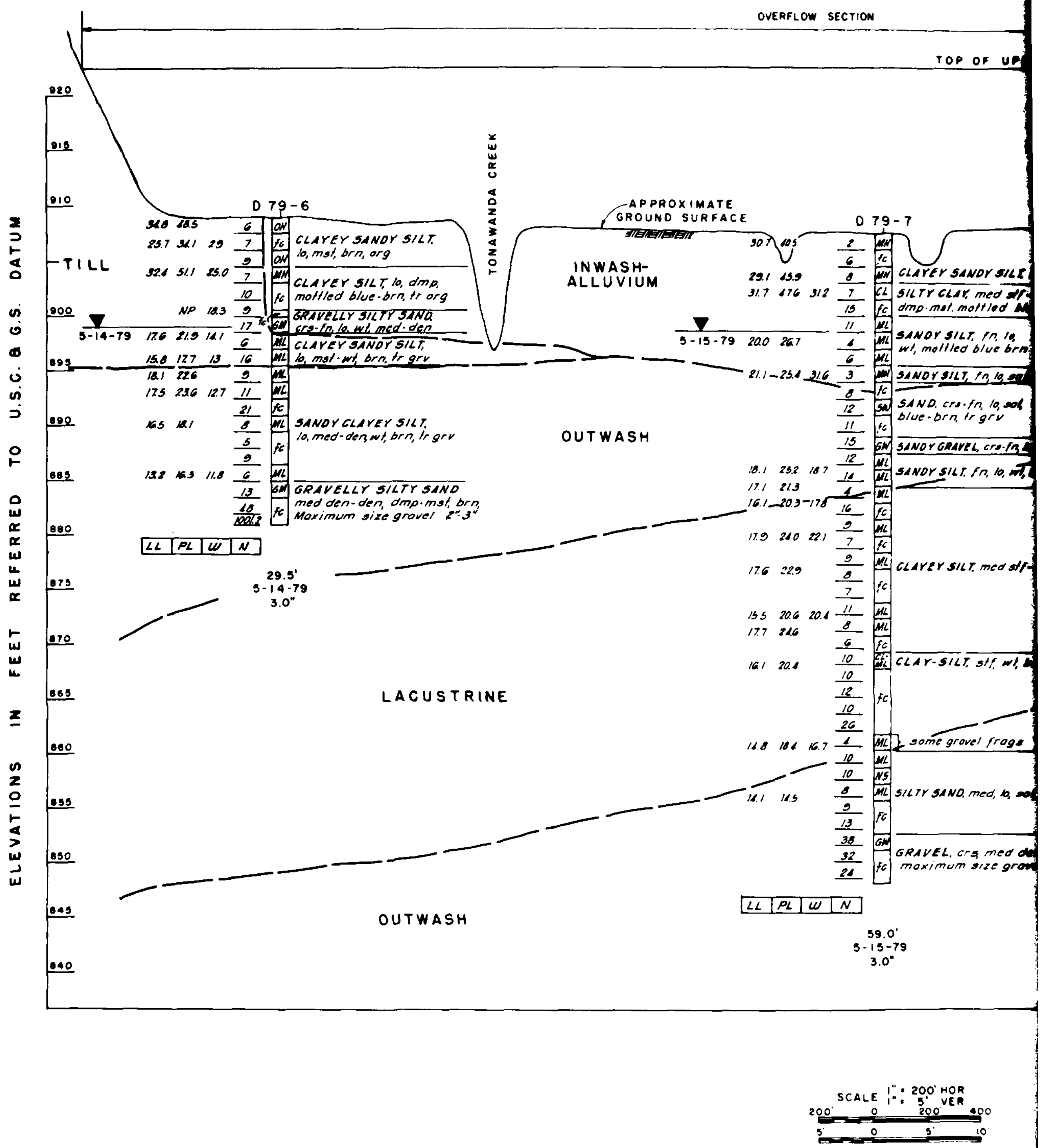
TO ACCOMPANY REP

PROPOSED USE	DIS[illegible]
RIPRAP, BEDDING COARSE AGGREGATE	6 MI.
RIPRAP, BEDDING	12 MI.
RIPRAP	18 MI.
FINE AGGREGATE	21 MI.
RIPRAP, BEDDING	21 MI.
RIPRAP, BEDDING	24 MI.
RIPRAP, BEDDING COARSE AGGREGATE	27 MI.
RIPRAP, BEDDING	14 MI.
RIPRAP, BEDDING	30 MI.
BEDDING, COARSE AGGREGATE	50 MI.
RIPRAP, BEDDING COARSE AGGREGATE	28 MI.
FINE AGGREGATE COARSE AGGREGATE	30 MI.

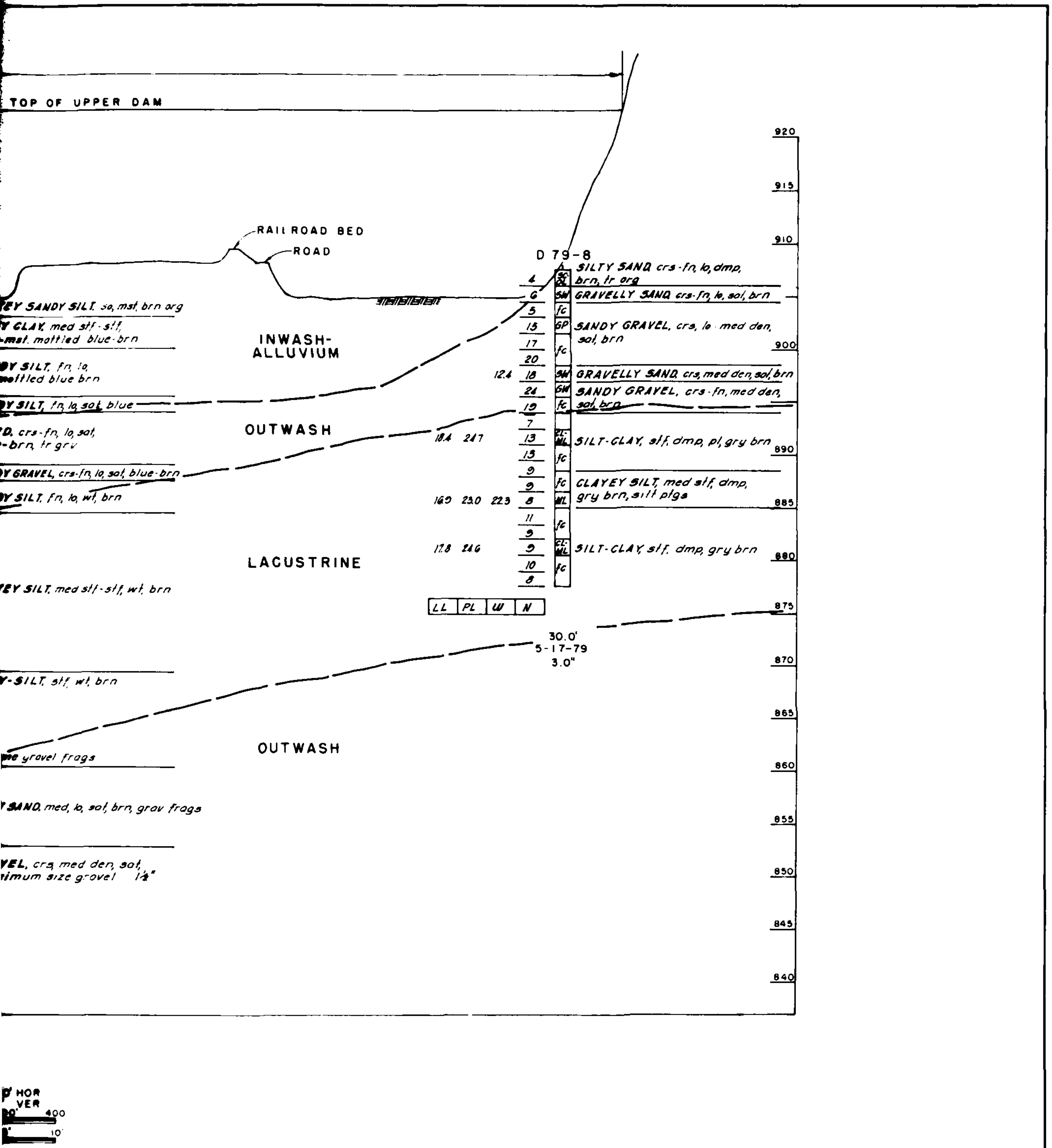
A CREEK WATERSHED, N.Y.
A RESERVOIR COMPOUND
(MODIFIED)

MATERIAL SOUR

NGINEER DISTRICT, BUFFAL
REPORT DATED: NOVEMBER 1979



OVERFLOW SECTION
TOP OF UP
ELEVATIONS IN FEET REFERRED TO U.S.C. & G.S. DATUM
920
915
910
905
900
895
890
885
880
875
870
865
860
855
850
845
840
D 79-6
TILL
CLAYEY SANDY SILT, lo, msl, brn, org
CLAYEY SILT, lo, dmp, mottled blue-brn, tr org
GRAVELLY SILTY SAND, crs-fn, lo, wt, med-den
CLAYEY SANDY SILT, lo, msl-wt, brn, tr grv
SANDY CLAYEY SILT, lo, med-den, wt, brn, tr grv
GRAVELLY SILTY SAND med den-den, dmp-msl, brn, Maximum size gravel 2"-3"
5-14-79
LL
PL
W
N
29.5'
5-14-79
3.0"
TONAWANDA CREEK
APPROXIMATE GROUND SURFACE
INWASH-ALLUVIUM
OUTWASH
LACUSTRINE
OUTWASH
D 79-7
5-15-79
CLAYEY SANDY SILT
SILTY CLAY, med stf, dmp-msl, mottled
SANDY SILT, fn, lo, wt, mottled blue brn
SANDY SILT, fn, lo,
SAND, crs-fn, lo, sat, blue-brn, tr grv
SANDY GRAVEL, crs-fn,
SANDY SILT, fn, lo, wt,
CLAYEY SILT, med stf
CLAY-SILT, stf, wt,
some gravel frags
SILTY SAND, med, lo,
GRAVEL, crs, med
maximum size grav
LL
PL
W
N
59.0'
5-15-79
3.0"
SCALE 1" = 200' HOR 1" = 5' VER
200
0
200
400
5
0
5
10



NOTES:

1. FOR LOCATION OF SECTION – SEE PLATE E1
2. FOR DESCRIPTION OF GEOLOGIC UNITS – SEE PLATE E1
3. FOR LEGEND FOR BORINGS AND ABBREVIATIONS – SEE PLATE E3

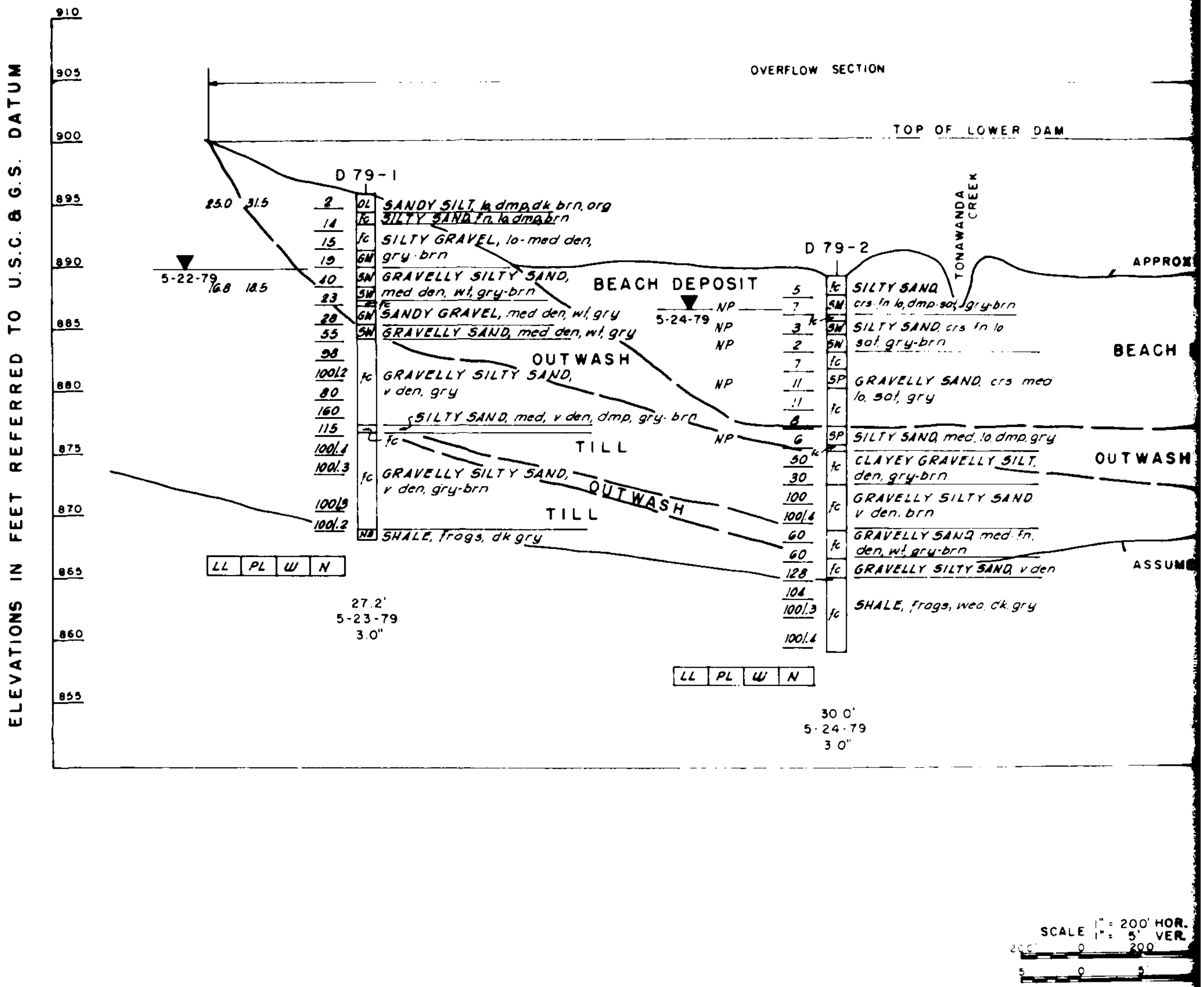
TONAWANDA CREEK WATERSHED, NEW YORK
BATAVIA RESERVOIR COMPOUND
(MODIFIED)

CENTERLINE PROFILE UPPER DAM

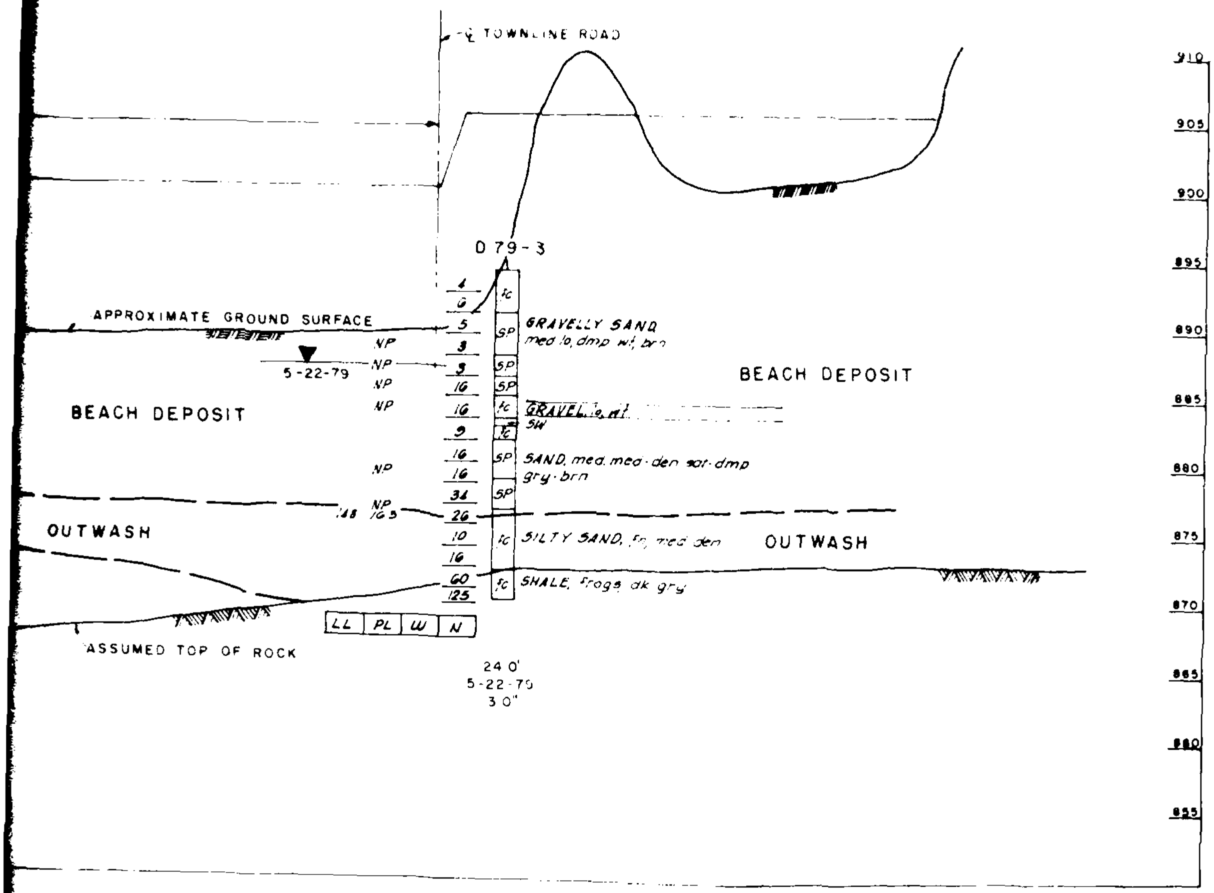
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED NOV. 1980

PLATE E6

1 2



ELEVATIONS IN FEET REFERRED TO U.S.C. & G.S. DATUM
910
905
900
895
890
885
880
875
870
865
860
855
OVERFLOW SECTION
TOP OF LOWER DAM
D 79-1
D 79-2
TONAWANDA CREEK
APPROX
BEACH DEPOSIT
BEACH
OUTWASH
TILL
SHALE, frags, dk gry
SANDY SILT, lo dmp, dk brn, org
SILTY SAND, fn, lo dmp, brn
SILTY GRAVEL, lo-med den, gry-brn
GRAVELLY SILTY SAND, med den, wt, gry-brn
SANDY GRAVEL, med den, wt, gry
GRAVELLY SAND, med den, wt, gry
GRAVELLY SILTY SAND, v den, gry
SILTY SAND, med, v den, dmp, gry-brn
GRAVELLY SILTY SAND, v den, gry-brn
SILTY SAND, crs-fn lo, dmp-sat, gry-brn
SILTY SAND, crs-fn lo sat, gry-brn
GRAVELLY SAND, crs-med lo, sat, gry
SILTY SAND, med, lo dmp, gry
CLAYEY GRAVELLY SILT, den, gry-brn
GRAVELLY SILTY SAND, v den, brn
GRAVELLY SAND, med-fn, den, wt, gry-brn
GRAVELLY SILTY SAND, v den
SHALE, frags, wea, dk gry
ASSUM
5-22-79
5-24-79
25.0 31.5
16.8 18.5
LL PL W N
27.2'
5-23-79
3.0"
30.0'
5-24-79
3.0"
SCALE 1" = 200' HOR. 1" = 5' VER.



1" = 200' HOR
1" = 5' VER.

NOTES:

1. FOR LOCATION OF BORINGS - SEE PLATE E1.
2. FOR DESCRIPTION OF GEOLOGIC UNITS - SEE PLATE E1.
3. FOR LEGEND FOR BORINGS AND ABBREVIATIONS - SEE PLATE E3.

TONAWANDA CREEK WATERSHED, NEW YORK

BATAVIA RESERVOIR COMPOUND

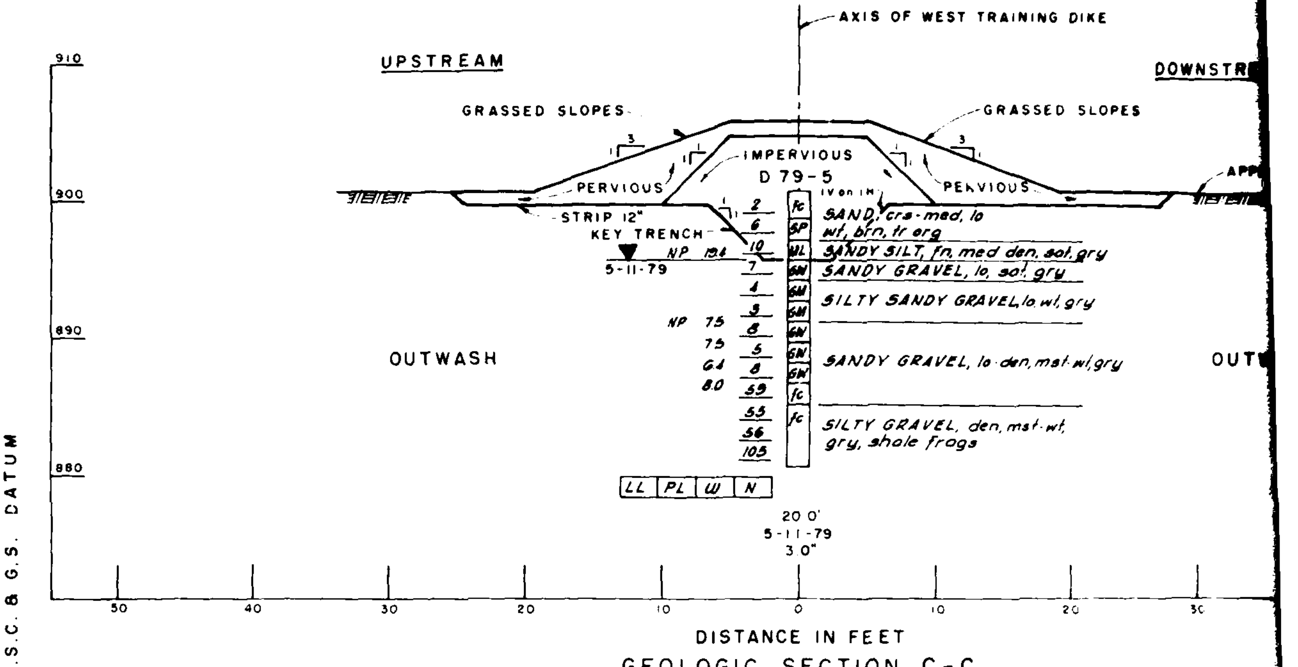
(MODIFIED)

CENTERLINE PROFILE
LOWER DAM

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED NOV 1980

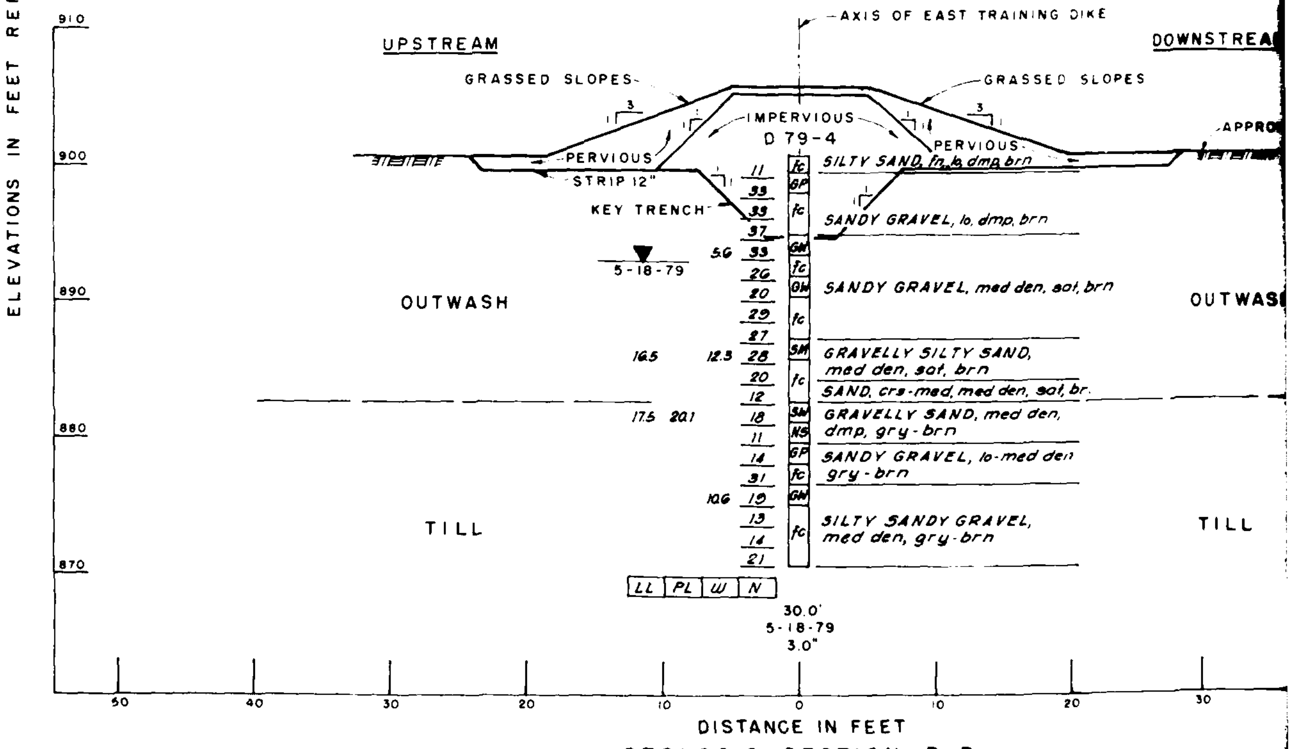
PLATE E7



GEOLOGIC SECTION C-C

WEST TRAINING DIKE

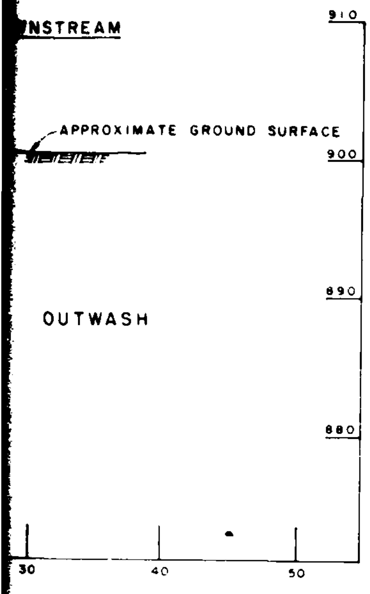
SCALE 1" = 5' HOR, 1" = 5' VER

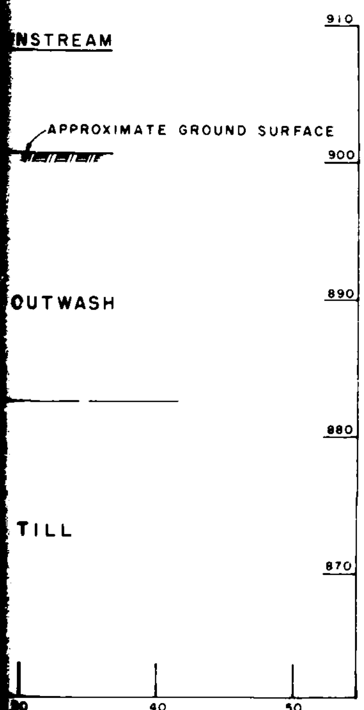


GEOLOGIC SECTION D-D

EAST TRAINING DIKE

SCALE 1" = 5' HOR. 1" = 5' VER





NOTES:

1. FOR LOCATION OF BORINGS - SEE PLATE E1.
2. FOR DESCRIPTION OF GEOLOGIC UNITS - SEE PLATE E1.
3. FOR LEGEND FOR BORINGS AND ABBREVIATIONS - SEE PLATE E3.

TONAWANDA CREEK WATERSHED, NEW YORK

BATAVIA RESERVOIR COMPOUND (MODIFIED)

GEOLOGIC SECTIONS

C-C WEST TRAINING DIKE

D-D EAST TRAINING DIKE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED NOV. 1980

1 2

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

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1980

APPENDIX F

NONSTRUCTURAL

BASE PLAN

U. S. Army Corps of Engineers
Buffalo District
Buffalo, New York

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TABLE

APPENDIX F

NON-STRUCTURAL BASE PLAN

F1. INTRODUCTION

Hundreds of structures, additional building sites, and hundreds of acres of farmland are susceptible to periodic flooding. Structural projects have been constructed in the Tonawanda Creek Watershed to diminish flooding somewhat. While all these efforts have contributed to flood damage reduction, a significant flood threat remains for unprotected areas as well as those areas with marginal protection. The existing flood threat could be alleviated by non-structural measures.

Non-structural measures are of a damage management nature. They include flood warning and emergency action, floodproofing, flood insurance, flood plain management (land use regulation), and permanent evacuation.

F2. FLOOD WARNING AND EMERGENCY ACTION

Whether an area is protected by one or a combination of flood protective measures, the possibility of flooding still exists. This may occur as a result of unanticipated storms producing flood flows and/or volumes exceeding design capacities of structural measures or natural capacities of channels. If, in June 1972, Tropical Storm Agnes had followed its northward path instead of turning out to sea, it would have surely resulted in considerable, if not disastrous, flood damage in the watershed.

To reduce damages and, especially, to prevent loss of life, emergency actions must be carefully planned so that they may be implemented promptly when an emergency situation arises.

Efficient evacuation depends upon an effective flood warning system. Most communities in the Tonawanda Creek Watershed do not have a formal flood warning system; however, general flood forecasting is provided by the National Weather Service. It is possible for residents of the lower Tonawanda Creek Watershed to receive flood warnings 24 to 36 hours in advance. With such warning time, orderly and efficient evacuation is possible provided there has been advance planning for it and an organization for carrying it out is ready. An important part of emergency action is the care of flood victims after they have been evacuated from the flood threatened area.

F3. FLOODPROOFING AND PERMANENT EVACUATION

Floodproofing consists of modifying individual buildings or providing external protection measures to reduce flood damage. While floodproofing can reduce interior damages substantially, exterior damages to individual buildings and the overall flooded area are usually not affected. Also, floodproofing can bring about a false sense of security and discourage the development of needed flood protection works. It can also tend to increase

the use of floodplains. Most important of all, if applied to a structurally inadequate building it can result in more damage than would occur if the building were not floodproofed. A structurally inadequate building should be modified to obtain soundness or removed from the flood vulnerable area.

Floodproofing and evacuation were evaluated for areas of like character throughout the watershed. The areas considered include:

the village of Attica through the village of Alexander;
the city of Batavia through the hamlet of Bushville;
the hamlet of Bushville to Hopkins Road in the town of Royalton;
the Hopkins Road to Sweet Home Road in the town of Amherst;
the Sweet Home Road to the mouth of Tonawanda Creek;
the floodplains of Ransom and Black Creeks; and
the floodplains of Mud Creek.

It was assumed that residential units could be floodproofed against flooding to depths of two feet above their first floors and that units not structurally adaptable to floodproofing measures would be permanently evacuated. Commercial units were assumed to be adaptable to floodproofing measures for all flood depths considered.

The floodproofing and permanent evacuation measures were considered for three levels of protection: Standard Project, 200-year and 100-year. The average annual benefit and costs of providing each level were estimated and compared. An economic evaluation of 100-year protection, found to be most cost-effective for all areas considered, is shown in Table F1.

The floodproofing and permanent evacuation measures are justified for all three levels of protection for the areas between Hopkins Road and Sweet Home Road and the area affected by Ransom and Black Creeks, and for the 100-year level of protection for the area affected by Mud Creek. However, relatively large amounts of residual damage remain with floodproofing measures in place. These residual damages are primarily related to problems of access, surveillance, building exterior and landscape damage. Also, sanitation and isolation problems would persist to affect the social well-being of residents in the Huron Plain.

F4. FLOOD INSURANCE

Flood insurance does not reduce flood damages and is not a true nonstructural measure for flood damage reduction. It only compensates for flood damages suffered. Federally subsidized flood insurance is available under the National Flood Insurance Program provided adequate land use regulations are implemented. The Flood Insurance Program is designed to provide economic relief to owners of existing structures vulnerable to flood damage but on the condition that the community take steps to insure that new development be constructed or floodproofed to at least the 100-year flood level. All identified flood vulnerable communities are required to join the Program in order to receive Federal or Federally-related financial assistance.

Table F1 - Economic Evaluation of Floodproofing and Permanent Evacuation Measures of the N-SBP

	Units 1/ Affected	Units 1/ Flood-proofed	Units 2/ Permanently Evacuated	Units 1/ Unprotected	Annual Cost	Annual Benefits	Benefit Cost Ratio
					$	$	
Attica through Alexander	30	20	0	10	3,900	2,700	0.69
Batavia through Bushville	1,965	1,891	74	0	448,900	144,000	0.32
Bushville to Hopkins Road	100	85	15	0	43,900	4,700	0.11
Hopkins Road to Sweet Home	512	358	47	107	172,100	306,000	1.78
Sweet Home Road to Confluence w/Ellicott Creek	1,738	1,738	0	0	224,400	65,000	0.29
Ransom & Black Creek	391	345	4	42	59,900	144,000	2.4
Mud Creek	185	71	0	114	11,200	36,000	3.21
Total	4,921	4,508	140	273			

Notes:

1/ Includes Residential & Commercial

2/ Residential Units Only

3/ Operation and Maintenance was estimated at $25 Per Unit Floodproofed, Per Year, or $25 x 4,508 = $112,700, say $15,000.

F5. FLOODPLAIN MANAGEMENT (Land Use Regulation)

The regulation of land use has an important place in any plan to reduce flood damage. It must be understood that the flood plain is an integral part of a stream system even if it is used only intermittently for the discharge of floodwaters. The purpose of flood plain regulation is to limit use of the flood plain so that damages suffered during inevitable periods of flooding will be minimal. Regulation of use of flood plains requires that a map outlining the areas affected by floods of different magnitudes be developed. With this data, regulations prescribing the best use of the flood plain can be developed. These regulations might include zoning, elevation of new residential development, or building codes requiring construction resistive to flood damage.

F6. PERMANENT EVACUATION

Permanent evacuation is another means of preventing flood damage. It consists of the permanent removal of buildings and other structures from flood vulnerable area and relocation of affected people to an area which is free from flooding. This generally involves purchasing the flood vulnerable land, demolishing or otherwise removing the buildings and other structures, cleaning up the debris, and landscaping the area. New sites are provided for buildings relocated. This is a high-cost method of flood dmaage reduction attractive only under unusual conditions or where the flood risks cannot be reduced by other means.

Application of this method alone for flood damage reduction in the Tonawanda Creek Watershed was deemed infeasible for all areas considered.

F7. NON-STRUCTURAL BASE PLAN

Communities in the Tonawanda Creek Watershed could deal effectively with the flood situation by implementing a combination of non-structural measures. The Non-structural Base Plan would provide for floodproofing to at least the 100-year level for the area between Hopkins Road and Sweet Home Road and for the areas affected by Ransom, Black and Mud Creeks. Pertinent data for this alternative is shown on Table N-SBP.

In addition to floodproofing, the N.-S. Base Plan would provide that flood plain management and a system for flood warning and emergency action be integrated to effectively complete the non-structural approach to the flood problem. A rigorous, well coordinated effort by local, State and Federal agencies, with the basis for decisions coming from the general public, would be made to plan for use of the flood plain in advance of development. The instruments for controlling future land use include: zoning ordinances; open-space and public land acquisition programs; and public policy discouraging the extension of streets and water and sewer lines into floodprone areas.

No matter what flood damage management plan is ultimately accepted, wise use of the flood plain is important. This usually calls for regulation. Also, because of the possibility that the capacities of flood protection works may be exceeded, a plan for evacuating all flood vulnerable areas should be developed.

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

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APPENDIX G

U. S. Army Corps of Engineers
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INPUT FROM FEDERAL AGENCIES

U. S. Army Corps of Engineers
Buffalo District
Buffalo, New York

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
100 Grange Place
Room 202
Cortland, New York 13045

October 23, 1980

Colonel George P. Johnson
District Engineer, Buffalo District
U.S. Army Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Johnson:

This constitutes our report on effects the flood control project for the Tonawanda Creek Watershed, Towns of Batavia and Alexander, Genesee County, New York, would have on fish and wildlife resources. It was prepared under the authority of and in accordance with Section 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). This report supersedes our report of April 16, 1980.

Authorization to study the feasibility of flood management in the Tonawanda Creek Watershed, New York, derives from a resolution of the Senate Committee on Public Works, United States Congress, adopted June 15, 1950. This authorization was expanded by resolutions of the House of Representatives Committee on Public Works, United States Congress, adopted August 16, 1950 and July 23, 1956. Present authorization provides only for a determination of project feasibility, whereas additional feasibility studies (General Design Memorandum), as well as the actual construction, have yet to be authorized and funded by Congress.

Engineering and geophysical data presented in this report are from the *Interim Report on Feasibility of Flood Management in Tonawanda Creek Watershed and Technical Appendices* (U.S. Army Corps of Engineers, 1979) and from communications with your office prior to February 15, 1980. Biological data are primarily from field reconnaissance conducted by personnel from your office and from our office in Cortland, New York.

Data were also taken from unpublished Hunter Use and Game Survey Reports for the Batavia Cooperative Hunting Area, New York State Department of Environmental Conservation, Avon, New York and from unpublished fisheries surveys conducted in the Tonawanda Creek basin by the State University of New York at Buffalo and Bio Systems Research, Inc., Buffalo, New York. Baseline habitat conditions were evaluated by an interagency team comprised of personnel from your office, the U.S. Fish and Wildlife Service, and the New York State Department of Environmental Conservation using the Service's Habitat Evaluation Procedures. Our analysis is based on a 100-year project life for the years 1980 through 2079.

This report has been reviewed and endorsed by the Division of Fish and Wildlife of the New York State Department of Environmental Conservation as signified by the attached letters from Director Kenneth F. Wich, dated February 20 and September 29, 1980.

DESCRIPTION OF THE PROJECT

The selected plan for flood management in the Tonawanda Creek Watershed is the Batavia Reservoir Compound (modified) (Fig. 1). The proposed plan is to construct two floodwater detention reservoirs (dry dams) on Tonawanda Creek for the primary purpose of reducing average annual flood damages in the lower basin by approximately 74 percent. At maximum floodpool, the reservoirs would inundate a tract of roughly 4,763 acres (1,929 ha) (about 894 acres (362 ha) in the upper reservoir and 3,869 acres (1,567 ha) in the lower reservoir) of bottomland between the Village of Alexander and the City of Batavia, Genesee County, New York.

The upper dam would be located approximately 200 feet (61 m) downstream of the Delaware Lackawanna Railroad (Conrail) embankment and would stretch 5,450 feet (1,661 m) across the Tonawanda Creek Valley (Fig. 1). The width by height dimensions of the dam would be 98 x 19 feet (30 x 5.8 m). This embankment would be designed to function as an emergency spillway with a top elevation of 922.5 feet (281.2 m). Approximately 2 feet (60 cm) of water would flow over the dam during a Standard Project Flood assuming a maximum pool elevation of 924.5 feet (281.8 m).

The principal outlet works for the upper reservoir would consist of a control structure, stilling basin, and outlet channel located at or near the intersection of the upper dam and Tonawanda Creek. The control structure would be a five-conduit reinforced concrete box culvert with the capacity to pass flows of 2,000 cfs (56 cms) under natural flow conditions and up to 10,700 cfs (300 cms) under the 100-year flood condition. Each conduit would be 11 feet wide by 11 feet high (3.4 x

3.4 m) and equipped with an electrically operable fixed wheel control gate. An upstream inlet flume would funnel water into the gated conduits. The inlet flume would consist of a reinforced concrete section located adjacent to the control gates and steel sheetpile wingwalls. The channel bottom between the wingwalls would be protected with 24-inch (60 cm) riprap placed on a 12-inch (30 cm) bedding layer. The riprap would extend from the concrete floor slab to a line 10 feet (3 m) upstream of the wingwalls. The stilling basin would be a reinforced concrete structure 61 feet (18.6 m) wide and 62 feet (18.9 m) long with a raised end sill 4 feet (1.2 m) high. A new outlet channel, starting at the stilling basin end sill, would be excavated normal to the dam and would extend downstream for approximately 1200 feet (366 m) to a junction with the existing creek channel. The outlet channel bottom, flaring from a width of 71 feet (21.6 m) at the stilling basin to 91 feet (27.7 m), would be protected with 24-inch (60 cm) riprap placed on a 12-inch (30 cm) bedding layer for a distance of approximately 100 feet (30.5 m). The meandering Tonawanda Creek channel immediately downstream from the upper dam would be abandoned.

The lower dam would be located approximately one-half mile (0.8 km) south of the City of Batavia and would stretch 5,600 feet (1,707 m) across the Tonawanda Creek valley (Fig. 1). The width by height dimensions of the dam would be 69 x 12 feet (21 x 3.7 m). This embankment is designed to function as an emergency spillway with a top elevation of 900 feet (274.3 m) from Creek Road westward for approximately 4,000 feet (1,219 m). Approximately 2.6 feet (80 cm) of water would flow over the dam during a Standard Project Flood assuming a maximum pool elevation of 902.6 feet (275.1 m). From Creek Road to the east abutment, and for a short distance at the west abutment, the embankment is designed as a non-overflow section with a top elevation of 905.5 feet (275 m) and grassed slopes.

The principal outlet works for the lower reservoir would consist of a control structure, stilling basin, and outlet channel located 900 feet (275 m) east of the intersection of the lower dam and Tonawanda Creek. The control structure would be a four-conduit reinforced concrete box culvert with the capacity to pass flows of up to 6,000 cfs (168 cms) under the 500-year flood condition. Each conduit would be 11 feet wide by 11 feet high (3.4 x 3.4 m) and equipped with an electrically operable fixed wheel control gate. An upstream inlet flume would funnel water into the gated conduits. The inlet flume would consist of a reinforced concrete section located adjacent to the control gates and steel sheet-pile wingwalls. The channel bottom between the wingwalls would be protected with 24-inch (60 cm) riprap placed on 12-inch (30 cm) bedding layer. The riprap would extend from the concrete floor slab to a line 10 feet (3 m) upstream of the wingwalls. The stilling basin would be a reinforced concrete structure 48.5 feet (14.8 m) wide and 62 feet (18.9 m) long with a raised end sill 4 feet (1.2 m) high. A new inlet channel, starting at the inlet flume, would be excavated normal to the dam and would extend upstream for approximately 500 feet (152 m) to a junction

with the existing creek channel. A new outlet channel, starting at the stilling basin, would be excavated normal to the lower dam and would extend downstream for approximately 100 feet (30.5 m) to a junction with the existing creek channel. The outlet channel bottom, flaring from a width of 48.5 feet (14.8 m) at the stilling basin to 70 feet (21.3 m), would be protected with 24-inch (60 cm) riprap placed on a 12-inch (30 cm) bedding layer for its entire length. The meandering Tonawanda Creek channel immediately upstream from the lower dam and west of the principal outlet works would be abandoned.

Several non-overflow training dikes would be located along the east and west sides of the Tonawanda Creek valley (Fig. 1). Along the east side, a dike would stretch 950 feet (290 m) across a natural saddle located approximately 1,000 feet (305 m) south of East Road. Along the west side, three dikes would be located approximately 500 feet (152 m) east of Route 98 in the reach between Cookson Road and the Lehigh Valley Railroad (Conrail) embankment. These dikes would stretch 3,330 feet (1,015 m), 600 feet (183 m), and 150 feet (46 m) across low areas in order to prevent possible overtopping of Route 98. The maximum height of these dikes varies from 5.5 to 9 feet (1.7-2.7 m). To provide the required interior drainage, each dike would have a gated culvert consisting of a 24- to 36-inch (60-90 cm) diameter reinforced concrete pipe, reinforced concrete headwalls and wingwalls, and automatic flap gates mounted on the reservoir side of each dike.

The two dams and four training dikes would be earthen fill structures having 1 vertical on 3 horizontal side slopes; the dikes would be seeded and the dams riprapped on both upstream and downstream faces. The riprap would be chinked with 6 inches (15 cm) of topsoil and seeded with crown vetch.

Construction of the dams and dikes would require stripping an area of 35.6 acres (14.4 ha). Of this total, 14.3 acres (5.8 ha) would be cleared and grubbed. Also, construction of the dams and dikes would require the filling-in of 8.9 acres (3.6 ha) of wetland associated with the lower reservoir.

Downstream from the upper reservoir a section of Peaviner Road and the existing bridge over Tonawanda Creek would require relocation due to the realignment of the creek channel in the vicinity of the principal outlet works. A 60-foot (18 m) span highway bridge would be provided over the new outlet channel from the principal outlet works. The abandoned Lehigh Valley Railroad (Conrail) bridge over Tonawanda Creek would be permanently removed to improve hydraulic conditions downstream of the lower reservoir.

The existing Tonawanda Creek channel within the lower reservoir would be cleared of snags and debris jams to ensure a channel capacity of roughly 2,000 cfs (56 cms). Dead trees along the channel banks and overhanging, partially uprooted trees would also be removed. The sections of abandoned creek channel would be utilized as spoil areas for waste materials from clearing and stripping operations associated with the construction of the upper and lower dams and from clearing and snagging operations along the existing creek channel within the lower reservoir.

Under the present plan, all lands lying within the reservoir floodpool boundaries would be placed under flowage easement with the private landowners. These lands could still be farmed, but 37 residences and 3 farmsteads in the lower reservoir and 8 residences in the upper reservoir would have to be purchased and removed.

DESCRIPTION OF AQUATIC AND TERRESTRIAL ECOSYSTEMS

General

The Tonawanda Creek Watershed, an area of about 648 square miles (1,678 square kilometers), is located in western New York and includes portions of Erie, Genesee, Niagara, Orleans, and Wyoming counties. It occupies parts of two physiographic provinces -- the Appalachian upland and the Erie-Ontario lowland. Tonawanda Creek, the major stream of the watershed, rises in the Cattaraugus Hills in the Town of Wethersfield in Wyoming County. From its source, approximately 1,929 feet (588 m) above sea level, the creek flows northward approximately 22 miles (35 km) through deep valleys with steep sides and slopes to enter the Erie Plain near the Village of Attica. From Attica, the creek continues to flow northward for nearly 20 miles (32 km) through essentially flat bottomland to the City of Batavia, where erosion resistant rock formations of the Onondaga Escarpment turn the creek's channel to a westward flow through the Erie Plain. Lands surrounding the creek and its tributaries consist primarily of farm fields and various types of natural open space, including grass fields, wetlands, brush, and forests. The creek also passes through residential, commercial, and industrial areas in the villages of Attica and Alexander, and in the City of Batavia.

Aquatic Resources

The portions of Tonawanda Creek and its tributaries lying within the project area are designated Class "A" waters by the New York State Department of Environmental Conservation (NYSDEC). Class "A" is the highest water quality category in New York's classification system, but the NYSDEC does not consider this area to be trout inhabited water (Class "A(t)"). While trout are not normally stocked in these waters, some brown trout have been found in the Little Tonawanda Creek tributary (Table 1).

A wide diversity of aquatic macro-invertebrates have been collected from Tonawanda Creek and the Little Tonawanda Creek tributary (Great Lakes Laboratory, 1976). In both creeks the aquatic macro-invertebrates collected were primarily indicative of relatively unpolluted stream conditions. The dominant macro-invertebrate groups sampled were amphipods, anisopterans (dragonflies), dipterans (midges, true flies, horse flies, and black flies), coleopterans (water beetles), hemipterans (water boatman, water striders, and water scorpions), decapods (crayfish), ephemeropterans (mayflies), gastropods (snails), isopods, lepidopterans (water moths), megalopterans (alderflies), oligochaetes (aquatic earthworms), sphaeriids (clams), trichopterans (caddisflies), and zygopterans (damselflies).

Tonawanda Creek meanders through numerous farm fields, but is relatively undisturbed by most farm-related activities. However, intensive agricultural practices in the watershed tend to increase water runoff and thereby result in an increased sediment load in the creek during wet periods. The creek also passes through brushlands and forested areas, and is well-shaded for most of its length by a thick growth of riparian vegetation. This shading tends to create a cool, glen-like situation along the creek, even during the warmest days of summer. The banks are steeply sloping and usually consist of sand or clayey mud. Fallen trees and branches stretch across the creek in many places, and these snags tend to collect woody debris behind them. Turbid conditions seem to prevail throughout the year, with the creek being clearest during low-flow conditions (usually in summer) and most turbid during periods of peak runoff. Current in the main creek channel is relatively slow and water depth is variable, ranging from as little as 4 inches (10 cm) in riffle areas to greater than 4.3 feet (1.3 m) in deep pools (Bio Systems Research, 1979). The largest tributary of Tonawanda Creek, Little Tonawanda Creek, varies greatly in character: the upstream stretches are low, clear, rocky, and have moderate flow, whereas the downstream stretches are more turbid, silt-laden, and have a slow current (ibid.). Several other tributaries are present and their physical conditions vary like those of Little Tonawanda Creek. A number of ponds and oxbows are located in the project area. These lentic environs are warm, turbid, have mud bottoms, and are sometimes connected to channels having intermittent flow conditions.

Fishing in Tonawanda Creek occurs primarily in the vicinity of automobile and railroad bridges, where access is best. Float-fishing is possible, but difficult because of snags and debris jams in the creek. Small tributaries, ponds, and oxbows are fished quite readily from shore. Sport fishes sought include smallmouth bass, largemouth bass, and northern pike. Brown trout are present in Little Tonawanda Creek and they probably sustain some fishing pressure. Available panfish species include the pumpkinseed, bluegill, green sunfish, rock bass, yellow

perch, and brown bullhead. Numerous forage fish are also present. A total of 29 species of fish have been found to occur in this portion of the watershed (Table 1).

Terrestrial Resources

Terrestrial vegetation consists primarily of cropland, hayfield, pasture, emergent marsh, shrub swamp, and forested wetland. These cover types also encompass wet meadows, riparian hardwood stands, and vegetation associated with railroad rights-of-way. Farmlands consisting of hay, pasture, and crops of corn, sunflowers, and beans tend to dominate the landscape.

Wet meadows are the most homogeneous of existing cover types and are dominated by introduced species of yellow and white iris. Other plants found in association with the iris were skunk cabbage, purple loosestrife, and various sedges and grasses. Few vertebrates were found in association with this cover type and those that do occur are usually associated with open water pools, or are only seasonally present. Gray treefrogs, leopard frogs, bullfrogs, kingbirds, bobolinks, red-winged blackbirds, barn swallows, spotted sandpipers, mallard ducks, and muskrats have been found in association with this cover type in late spring and summer, and migrating shorebirds and waterfowl have been observed to make extensive use of these areas in spring and fall.

Emergent marshlands typically have a heterogenous mixture of open water and several species of cattail. Other plants found in association with cattail marshes were willow, purple loosestrife, yellow iris, white iris, water parsnip, water hemlock, nightshade, sensitive fern, and various horsetails, sedges, and grasses. These areas usually have some standing water throughout the year and have much intrinsic value to wildlife. Some species, including many frogs, toads, salamanders, and birds, require these areas for their seasonal breeding activities and for the development and the raising of young. Other species, such as barn swallows, tree swallows, and kingfishers, use these areas solely for feeding, whereas fish, green frogs, bullfrogs, water snakes, aquatic turtles, and some birds are year-round residents. Migrating waterfowl, herons, and shorebirds use these areas extensively in spring and fall.

Shrub swamps are comprised of woody species such as red-osier dogwood, silky dogwood, arrow-wood, buckthorn, slippery elm, hawthorne, willow, eastern cottonwood, and white and green ash. Herbaceous species present include purple loosestrife, yellow iris, bindweed, Joe-Pye-weed, and various grasses, sedges, and legumes. Wildlife use is extensive and many resident and non-resident species have been observed in these areas (Table 2). Most shrub species provide an important winter food resource for resident birds and mammals, and for migrant birds in spring and fall.

Forested wetlands vary from permanently flooded to seasonally dry and the plant species composition tends to vary with the moisture regime. The wettest areas are dominated by green ash, silver maple, red maple, and willow. Other species associated with wet areas include silky dogwood, buttonbush, slippery elm, honeysuckle, water parsnip, water plantain, cardinal flower, and fringed loosestrife. Drier sites are dominated by American beech, shagbark hickory, bitternut hickory, red oak, white oak, and sugar maple. Other species in dry sites include silver maple, green ash, choke cherry, ironwood, witch-hazel, buckthorn, hawthorne, wild grape, wild rose, woodbine, Christmas fern, blue cohosh, enchanter's nightshade, beggarticks, and May-apple. Forested wetlands have a diverse vertebrate fauna associated with them (Table 2) and are an important component of the terrestrial ecosystem, providing, for example, many nesting sites for birds, denning sites for snakes and mammals, and cover for terrestrial amphibians.

Railroad rights-of-way possess a diverse floral association that includes forests, shrublands, and old-field herbaceous situations. Species most intimately associated with these rights-of-way include hawthorne, slippery elm, staghorn sumac, willow, box-elder, common elderberry, arrow-wood, buckthorn, red-osier dogwood, woodbine, and wild grape. Herbaceous species found were numerous and include teasel, milkweed, Queen Anne's lace, poison-ivy, cow parsnip, touch-me-not, sorrel, curled dock, and various grass species. The faunal component was equally diverse (Table 2), while the diversity of both the flora and fauna seemed richest on the unmanaged and abandoned rights-of-way.

In general, and as a group, amphibians are well represented in the project area (Table 2) and they are quite abundant. The consistently damp soil conditions seem to favor frogs and toads, but may be limiting for salamanders. Seasonal ponds, emergent marshes, shrub swamps, and forested wetlands are used by these species for their spring breeding activities. Green frogs and bullfrogs spend both their larval and adult life stages in these aquatic habitats, whereas wood frogs, gray tree frogs, spring peepers, American toads, and the Jefferson's and blue-spotted salamanders spend their adult life in shrubby and wooded areas. Adult western chorus frogs and northern leopard frogs spend the summer in grassy fields and wet meadows. The more aquatic amphibians, including the green frog, bullfrog, and northern leopard frog, overwinter in the mud at the bottom of aquatic habitats, whereas the more terrestrial species tunnel into the soil of upland habitats.

Reptiles are represented by at least six snakes and three turtle species (Table 2), but this group is generally quite secretive and could be more diverse than is indicated by the available information. Snakes are wide ranging and utilize most of the various habitats available to them in the project area, with the exception of water snakes which are restricted to aquatic areas. The three turtle species are primarily aquatic; the

painted turtles and snapping turtles being most common in ponds, marshes and swamps, whereas the wood turtles are restricted to streams and associated riparian habitats and forested wetlands.

The avian component constitutes a visible and integral part of the Tonawanda Creek basin fauna. In numbers of species, birds were the most abundant vertebrate group. A diversity of habitat types interspersed with intensive agriculture provided what seemed to be excellent conditions for successful avian reproduction. Avian species observed during spring and summer breeding bird surveys in 1979 are listed in Tables 2 and 3. Birds observed in the basin during spring and summer, but not known to breed there, were the great blue heron, great egret, American bittern, and red-bellied woodpecker.

Aside from the use of the basin by breeding birds, there is considerable use of the area during spring and fall by migrants, and in summer by non-breeders. In the spring of 1979, two separate flocks of approximately 800-1,000 Canada geese each were observed on partially flooded farmlands at two locations near the main creek channel and within the bounds of the lower reservoir floodpool. The basin seems to serve as an alternative feeding and resting area for the enormous numbers of migrating ducks and geese that stop at nearby Iroquois National Wildlife Refuge each spring. Great blue herons, usually single but sometimes in flocks of 10-12, were observed throughout the basin during the spring and summer of 1979. One such flock was observed regularly in the large wetland complex near the junction of the Erie and Delaware Lackawanna (Conrail) railroads.

A diverse mammalian fauna is present in the Tonawanda Creek watershed (Table 2) and a wide variety of habitats are utilized, including marshes, swamps, forests, and agricultural lands. Mink, muskrats, raccoon and white-tailed deer seemed most abundant and were found in very close association with Tonawanda Creek and adjacent forested wetlands. Two important fur-bearers, beaver and river otter, were not observed during field reconnaissance, but both species have been previously reported from the Batavia-Alexander area by State biologists.

Public hunting is permitted on many private lands through cooperative agreements between landowners and the New York State Department of Environmental Conservation. The trapping of furbearers is also pursued, but there is no provision for this activity on Coop lands. Game species taken by hunters include raccoon, red fox, eastern gray squirrels, eastern cottontail rabbits, white-tailed deer, woodcock, ring-necked pheasant, and various ducks, geese, and rails. Furbearers taken by trappers include mink, muskrat, and raccoon.

The five major terrestrial habitat or land-use types in the project area were evaluated by an interagency team on September 20-21, 1979 using the Service's Habitat Evaluation Procedures (U.S. Fish and Wildlife Service, 1979a). Baseline habitat data were established by measuring and/or estimating the physical and vegetative habitat characteristics important to the wildlife species used in the evaluation. The evaluation elements (wildlife species) utilized (Table 4) were selected as being representative of the wildlife forms present in the project area and include species that are: (1) economically important; (2) of high public interest; (3) good indicators of habitat quality; and (4) of particular interest due to restricted range, high vulnerability, and/or special habitat requirements. The habitat inventory characteristics measured and/or estimated (Table 5) were derived from life history accounts developed for this particular evaluation (U.S. Fish and Wildlife Service, 1979b). Cover maps were prepared (Figures 2 and 3) and surface area was estimated based on maximum floodpool elevations provided by your staff in August, 1979, (922.5 feet (281.2 m), upper floodpool; 900 feet (274.3 m), lower floodpool). Table 6 depicts the baseline Habitat Suitability Indices (HSI), the surface area (hectares), and the Habitat Units (HSI x hectares) determined for each habitat type. HSI is an estimate of the relative value of a particular habitat type to the wildlife species used in the evaluation. For comparison, forested wetland received the highest rating for wildlife (HSI=0.803) and cropland the lowest (HSI=0.605).

PROJECT IMPACTS ON AQUATIC AND TERRESTRIAL ECOSYSTEMS

General

No comprehensive studies have been made to assess the effects of dry dams and their operation on either aquatic or terrestrial ecosystems; therefore the beneficial and adverse impacts of the Batavia Reservoir Compound on fish and wildlife are treated primarily in terms of the impacts that we are best able to evaluate. These are generally short-term effects, but the long-term effects of dry dams are also considered where there is sufficient information available to undertake a cogent analysis of potential project impacts.

Aquatic Resources

The construction of dry dams, lateral dikes, and outlet works could result in the potential for erosion of soil into the creek and the re-suspension of bottom sediments, resulting in an increased level of turbidity in the creek in the immediate vicinity of and downstream from project construction and maintenance activities. The increased level of

turbidity could then stress fish and macro-invertebrate populations, especially fish eggs and larvae, which are particularly sensitive to changes in the concentration of suspended solids. Filter-feeding invertebrates would be the most adversely affected invertebrate group. However, fish are usually more sensitive to suspended solids than are most invertebrates. Stern and Stickle (1978) reviewed the effects of turbidity in aquatic environments and listed: (a) thickening of gill lamellae, (b) excessive mucous secretion, (c) abrasion of branchial epithelium, and (d) respiratory distress as the potential stressing effects on fish from high concentrations of suspended solids. They also cited the clogging of opercular cavities and gill filaments with clay particles as factors leading to death. Suspended solids were reported to cause a delay in the hatching of fish eggs, often for several hours. Turbidity and suspended solids concentrations lower than those necessary to cause death or physiological injury may also produce other responses, including a disturbance in the normal population social structure and a general reduction in activity that may reduce the fishes ability to locate food and increase their susceptibility to predation (Heimstra *et al.*, 1969). Many of these effects would be expected to occur during and immediately following construction activities. They would be particularly adverse if construction were to take place during late spring and early summer when most fish breed (spawn) and when eggs, larvae, and young fish are developing. High suspended solids concentrations would be least harmful to fish if they were present during the winter months rather than in summer.

The retention of flood waters and their regulated release would have both beneficial and adverse effects on the aquatic ecosystem. Reservoir regulated discharges, which are held at or below the bank-full stage most of the time, would reduce bank erosion and bed scour and decrease the amount of sediment picked up from the stream bed or brought in from the flooding of bottomlands (Neel, 1963). These same conditions would extend under some conditions the period of increased turbidity in Tonawanda Creek beyond that found under flooding conditions without the project. Whereas most flooding would pass suspended particulate matter through in less than three days, the project would hold and release turbid floodwaters for as long as 9.8 days. Despite the settling out of suspended particulates in the reservoirs, some of the material would be resuspended by waters leaving the reservoir compounds. The prolonged turbid conditions could then severely stress fish and macro-invertebrate populations both downstream from and within each of the reservoir compounds. The potentially adverse effects of these conditions on aquatic resources would be essentially the same as those discussed in the above paragraph and they warrant no further discussion here. It should be noted, however, that while most fish will survive the normal increase in turbidity experienced under annual flooding, the effects of prolonged turbidity could be adverse.

The severity of any adverse effects would be increased if flooding were to occur during late spring or summer when many fish species are breeding (spawning) and when eggs, larvae, and young fish are developing.

The removal of snags and debris from the main creek channel would result in both beneficial and adverse impacts. Snag removal would permit the free passage of boats along the creek and therefore result in greater opportunities for public use of fish and wildlife resources. On the other hand, the snags, debris, and associated sediment deposits create significant habitat for macro-invertebrates, fish, frogs, and turtles. Their removal would reduce both the availability and the diversity of aquatic habitats. Many aquatic insects, including collectors (caddisflies), scrapers (mayflies), and predators (stoneflies and hellgrammites), are all common inhabitants of log and debris jams (Hynes, 1970). Many fish species congregate near obstructions (ibid.), and frogs and wood turtles use them for shelter and basking sites. Sediment deposits (which would be eroded if the snags were to be removed) serve as substrates for burrowing invertebrates such as chironomids, ephemeropterans, anisopterans, annelids, crustacea, and molluscs (Hynes, 1970; Anderson _et al._, 1977). Detritivorous invertebrates utilize the organic matter and/or the micro-flora of sediments as a food resource (Anderson _et al._, 1977). Any shift or reduction in the macro-invertebrate population would cause a reduction in the productivity of fish species dependent upon that resource.

Riparian vegetation damaged or destroyed during snag removal could result in increased stream temperatures through increased incipient solar radiation received at the surface of the creek (Ringler and Hall, 1975). Increased water temperatures would significantly affect the quality of the aquatic environment, potentially resulting in a change in the structure of the aquatic community.

The construction of dry dam outlet works would inhibit to some extent the normal movements of fish species present in Tonawanda Creek. Northern pike, white suckers, and various other fish species are known to migrate to spawning areas; therefore if the outlet structures impede their passage, either physically or through changes in fish behavior, then reduced reproduction would likely occur for the affected species, along with a change in the structure of the fish community.

The flooding of one or both of the reservoir floodpools would result in some fish moving out of their normal habitat and into the temporary reservoirs. With subsequent drawdown, some stream species could become stranded in permanent pond habitats, whereas others could become stranded in ponds or pools of water that eventually go dry. In either case, some fish mortality could be expected. Should flooding occur during the spawning season of a particular species then these activities would likely be suspended and in some cases an entire season of reproduction

could be delayed or possibly lost. If developing eggs should become covered with sediments deposited by flood waters then significant mortality could be expected at that life stage.

Terrestrial Resources

Construction of the Tonawanda Creek Flood Control Project would necessitate the stripping of about 35.6 acres (14.4 ha) of wildlife habitat for dry dam and lateral dike placement. These habitats provide shelter, food resources and breeding sites for many amphibians, reptiles, birds, and mammals found in and around the location of the proposed flood management structures. We estimate that approximately 9.2 Habitat Units would be lost due to the construction of these structures (Table 7).

Streamside activities necessary for snag removal would disturb riparian vegetation that both stabilizes the creek banks and provides wildlife cover. Riparian areas would be further affected by the placement of dams across the creek and the abandonment and filling-in of portions of the creek channel. These areas provide optimal habitat for some species such as the mink and wood turtle, thus damage to riparian areas could have significantly adverse effects on wildlife found in that habitat, including a significant reduction in species diversity and carrying capacity in remaining habitat.

Many amphibians, reptiles, birds, and mammals could be significantly affected by complete inundation of terrestrial habitats. Whereas most vertebrate communities can adapt to a permanent change in water level, they cannot respond effectively to rapid and irregular short-term inundation; therefore significant mortality could occur, especially during the breeding/nesting season should inundation occur at that time. For reptiles and birds, inundated eggs and/or young would result in a significant loss of embryos and/or nestlings for a particular year. Similar mortality could occur for mammalian young should their dens or nests become flooded while the young are still in early stages of development. Flood-water inundation would force many wildlife forms to higher, unflooded areas resulting in unnaturally high concentrations of wildlife on floating debris and on projecting trees and land areas. These concentrations would then result in increased predation and competition, and also in increased stress that would likely result in death for some individuals. Thus, the short-term effects of flood-water inundation could be significantly adverse.

The physical presence of the dry dams would act as a barrier to the normal movement and dispersal of many vertebrate species. Smaller vertebrates, such as salamanders that migrate to breeding ponds, would be most affected, whereas large species, such as deer, would have sufficient mobility to pass around the ends of the flood control structures and therefore would be less affected.

The inundation of terrestrial habitats by flood waters retained by the proposed dry dams would result in some significant adverse impacts on wildlife resources and their habitats. The most severe changes in plant species composition and abundance would likely occur in areas immediately upstream of the dry dams. These areas often become "mudflats", as they are flooded most frequently and for the longest duration, and because suspended sediments and debris tend to be deposited there. Erosion and sedimentation are continuous processes on reservoir mudflats and successive floodings tend to keep vegetation in an immature state (Wilson and Landers, 1973). The current trend of keeping much of the upper reservoir lands in hay and rowcrops (about 37 percent of the total area), as well as the greater duration of flooding expected with project implementation, will act to hasten the early development of mudflats in the upper floodpool. Mudflat formation in the lower reservoir is expected to be less severe due to the lesser frequency of flooding there, although the percentage of land in hay and pasture is essentially the same (about 39 percent of the total area).

Flooding imposes complex stresses on many vascular plants, most of which arise from the depletion of oxygen in the flooded soil (Whitlow and Harris, 1979). In addition to anaerobic soil conditions, plant age, plant size, flood depth, flood duration, flood timing, substrate composition, siltation, and wave and ice action are all factors that determine survivorship when plants are flooded (McKim et al., 1975; Whitlow and Harris, 1979). The time at which a flood occurs during the growing season, along with the duration or period that an area is flooded, can have a significant impact on the survival of vegetation. Whereas dormant season flooding usually has no effect on woody plants, seedlings flooded after leaf flush are very susceptible to damage (Broadfoot and Williston, 1973). In a study of six New England flood control reservoirs, McKim et al. (1975) observed that smaller (less than 14-inch diameter) and younger trees were more affected by inundation than larger, mature trees, but that all trees inundated for more than 90 hours were affected to some degree. These authors further observed that ice conditions associated with winter flooding caused extensive damage to trees on floodplains. Low-growing, shrubby vegetation is very susceptible to flood damage, but may recover quickly through resprouting.

To determine the effects of operating the proposed Batavia Reservoir Compound (modified) on the terrestrial ecosystem, we estimated without- and with-the-project Habitat Unit changes and net average annual gain and loss of Habitat Units according to habitat type (Tables 8, 9, and 10, respectively). The data show a net gain of 103.4 Habitat Units for emergent marsh (EM) and pasture (P) habitat, and a net loss of 421.2 Habitat Units for shrub swamp (SS), forested wetland (FO), and cropland

(C) habitat. The indicated Habitat Unit changes reflect predicted annual changes in plant species composition and community structure that would likely result from flood-water inundation, mudflat formation (sedimentation), and natural and project-influenced plant succession, and presume that the following assumptions would hold true should the project, as described herein, be implemented:

1. That currrent land-use patterns would remain unchanged over the life of the project (100 years).

2. That 35% of the upper floodpool lands and 5% of the lower floodpool lands would develop into unstable mudflats under with-the-project conditions and that all mudflats would form within the first 25 years of project life.

3. That all habitat types would be equally affected by mudflat formation, except that emergent marshlands in the lower floodpool would remain unaffected (0% loss) and that cropland in the upper floodpool would be severely affected (60% loss).

4. That the mudflats would have little or no wildlife value (HSI=0.000).

5. That the following changes in habitat composition would occur over the period of analysis due to natural and project-induced plant succession:

	Without-the-Project Conditions			With-the-Project Conditions		
	Present Habitat	% of Habitat Converted	Resulting Habitat	Present Habitat	% of Habitat Converted	Resulting Habitat
Upper Pool	EM	0%	EM	EM	0%	EM
	SS	75%	FO	SS	50%	FO
	FO	0%	FO	SS	25%	EM
	P	25%	SS	FO	20%	EM
	C	0%	C	P	25%	SS
	--	---	--	P	25%	EM
	--	---	--	C	20%	SS
	--	---	--	C	20%	EM
Lower Pool	EM	0%	EM	EM	0%	EM
	SS	80%	FO	SS	80%	FO
	FO	0%	FO	FO	10%	EM
	P	10%	SS	P	10%	SS
	C	0%	C	P	10%	EM
	--	---	--	C	20%	SS

Construction of the project would result in the loss of some public access to lands and waterways in the basin and in the freedom of movement across lands and along watercourses. The loss of public access to terrestrial and aquatic areas would occur primarily through construction of the dry dams. These structures would deter, to some extent, the public's ability to enjoy the benefits of the area's wildlife resources. Of particular significance would be the severing of the Batavia-Alexander Recreational Trail by the lower dam. The trail is currently owned by Genesee County and is essentially that portion of the abandoned Erie Railroad right-of-way that runs from Law Street to Peaviner Road. This elevated pathway passes through a diverse assemblage of habitat types (Fig. 3) and possesses a unique floral association that is attractive to various forms of wildlife. The trail is currently used for hiking and cross-country skiing, as well as for fish and wildlife related recreational activities such as fishing and bird-watching. Genesee County plans to resurface and in other ways improve this pathway for multiple recreational uses. Estimates of public use show moderate (present) to heavy (projected) use of the trail:

	Present Use/Unimproved (persons-per-day)	Projected Use/with Improvements (persons-per-day)
Weekdays	15-25	60-80
Weekends	30-40	100-250

With the construction of the lower dam the right-of-way would become a dead-ended structure and decrease in its realized and potential recreational value.

PLAN OF DEVELOPMENT FOR AQUATIC AND TERRESTRIAL ECOSYSTEMS

In order to protect aquatic resources, a plan should be developed by the Corps of Engineers in cooperation with and approved by the New York State Department of Environmental Conservation, the U.S. Fish and Wildlife Service, the U. S. Soil Conservation Service, and the U. S. Environmental Protection Agency, to minimize the amount of project-caused erosion, siltation, and water pollution in Tonawanda Creek and its tributaries during and immediately after construction.

To mitigate the potentially adverse effects of the dry dams on normal fish movements in Tonawanda Creek, outlet works associated with the upper and lower dams should be constructed in such a manner as to permit upstream-downstream fish passage during normal flow (non-flood) conditions. A plan detailing the provisions and/or facilities for fish passage through the outlet works should be prepared by the Corps of Engineers in cooperation with and approved by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service. All necessary structures should be incorporated into the overall design, construction, operation, and maintenance plan for this project, and they should be provided at project cost.

All construction activities associated with instream or streambank areas, including snag removal, should be restricted to a period when impacts on fish and wildlife resources would be minimal. We anticipate that the least damage to those resources would be incurred if construction were to take place during the period from July 15 through November 15, when surface runoff and stream flow are generally lowest, and thus avoiding both the critical overwintering period and the breeding season of many fish and wildlife species.

Prior to the removal of snags from the creek and dead trees from along its banks, a plan should be developed by the Corps of Engineers in cooperation with and approved by the New York State Department of Environmental Conservation and the U.S. Fish and Wildlife Service to minimize the adverse effects of these activities on fish and wildlife resources. The following provisions should be included in the plan: (a) that stumps and logs embedded in the creek banks be cut rather than pulled and that logs deeply embedded in the creek bottom be left undisturbed in order to maintain complexity and hence diversity in the aquatic ecosystem; (b) that large dead trees along the channel banks which are in no imminent danger of toppling into the creek be left standing to provide essential denning, nesting, resting, and feeding sites for wildlife; and (c) that streamside activities be avoided where mature riparian growth, particularly box-elder and willow, could be damaged.

Sections of Tonawanda Creek that are cut off or abandoned should be plugged at their upstream and downstream ends with clean fill to provide conservation pools for fish and wildlife and all riparian vegetation associated with these areas should be left undisturbed.

The banks of Tonawanda Creek and upland areas surrounding the proposed dry dams and lateral dikes that are disturbed during construction activities, as well as riparian areas disturbed during snag and dead tree removal, should be revegetated as soon as possible after construction to mitigate the loss of wildlife habitat. A revegetation plan should be

developed for the project in cooperation with and approved by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service. The plan should include the monitoring of growth conditions to ensure that revegetation is successful and the replacement of dead or dying plant species. All replanting, maintenance, and monitoring activities should be funded as project costs.

To mitigate the potentially adverse effects of prolonged flooding on fish and wildlife and their habitats, flood waters should be retained in the reservoir for the shortest period of time necessary to reduce downstream flood damages. Fish and wildlife and their habitats would then have a greater potential for recovery if the duration of flooding was minimized; however, the immediate and irreversible effects of complete inundation would still be realized and could not be mitigated.

Valuable wetland complexes should be protected from complete inundation. The more important of these areas are those wetlands located east of Old Creek Road and within the upper reservoir floodpool (stippling in Fig. 2) and east of Creek Road and within the lower reservoir floodpool (stippling in Fig. 3). Wetlands in the lower floodpool could be protected by shallow dikes and flap gates; those in the upper floodpool would require either a lengthy dike running parallel to the Erie-Delaware Lackawanna Railroad (Conrail) embankment or the raising of the railroad bed to an elevation above that of the maximum floodpool, the latter method being most desirable. However, the estimated cost for the protection of upper reservoir wetlands is $2,400,000. Because of this high cost and the potential adverse environmental effects that could result during the replacement of the railroad embankment, a more practicable solution would be to compensate for predicted resource damage and losses through in-kind compensation; that is, by purchasing another equally valuable wetland complex outside of the maximum floodpool boundaries, and subsequently managing it for fish and wildlife. The area of wetland that would need replacement is approximately 111.6 acres (45.2 ha), including 37.3 acres (15.1 ha) of emergent marsh and 74.6 acres (30.2 ha) of shrub swamp. We estimate that the protection of wetlands in the lower reservoir floodpool would cost $19,000 ($15,500 for initial construction and $3,500 for annual operation and maintenance) and that the purchase and management of wetland habitat to compensate in-kind for resource damage and losses in upper reservoir floodpool wetlands would cost $69,600 ($67,800 for initial land purchase and $1,800 for annual operation and maintenance). All funds for wetlands protection, and replacement and management, should be funded as project costs, and all needed protective structures should be incorporated into the overall design, construction, and maintenance of the flood control project.

Project-caused Habitat Unit losses should be compensated for through the purchase and management of habitat that is equivalent in wildlife value and located outside of the maximum floodpool boundary. Estimates of areas needed for compensation were determined through the coordinated efforts of biologists from the Corps of Engineers, the New York State Department of Environmental Conservation, and the U. S. Fish and Wildlife Service. Relative Importance Values (RIV's) were developed for each of the habitat types in the project area (Tables 11-13). Using the RIV's, adjustments were made from predominately cropland acreage to predominately forested wetland acreage (Table 14). Forested wetland was selected as the habitat type most desireable for acquisition (a) because it is the wetland type that would be most affected by this project, and (b) because of its high value (HSI=0.803, RIV=0.91). To ensure equitable compensation of habitat losses, all lands considered for purchase should first be rated for wildlife value by an interagency habitat evaluation team comprised of biologists from the Corps of Engineers, the New York State Department of Environmental Conservation, and the U. S. Fish and Wildlife Service. We estimate that approximately $335,700 would be needed to purchase lands for compensation of Habitat Unit losses and that $8,950 would be needed for management (annual operation and maintenance) of lands during the life of the project. All costs indicated should be funded as project costs and all lands acquired to compensate for Habitat Unit losses should be administered by the New York State Department of Environmental Conservation under a mutually agreeable plan developed by the Corps of Engineers, the New York State Department of Environmental Conservation, and the U. S. Fish and Wildlife Service. The New York State Department of Environmental Conservation has responded favorably to the possibility of managing mitigation lands resulting from this project and would most favor the purchase of lands adjacent to or near the site of the flood control project. State biologists have identified areas most desireable for acquisition (see attached Letter of Concurrence dated September 29, 1980). These areas should be given first priority for purchase when mitigation plans are finalized.

Loss of public access to lands and waterways and of free movement across lands and along watercourses should be compensated for by providing some means to walk and/or portage boats across the dams in the vicinity of the main creek channel and to permit passage along the Batavia-Alexander Recreational Trail. These problems could be remedied by (a) the construction of paths or stairways across the dams in the vicinity of the main creek channel, and (b) the construction of a sloping, earthern-fill ramp from the surface of the recreational trail to the top of the lower dam where it crosses the trail. With snag removal in the main creek channel, it

could be expected that float-fishing and other boating recreation in the creek would increase; therefore it would be essential to provide a means to facilitate portaging, as well as to provide safe passage across the dams for hunters, fishermen, etc. The construction of paths or stairways would facilitate public use of fish and wildlife resources and compensate, in part, for loss of public access to and across lands in the basin. Use of the Batavia-Alexander Recreational Trail is also expected to increase as Genesee County plans to resurface and in other ways improve this pathway for multiple recreational uses. Bird-watching, fishing, and other fish and wildlife related recreational activities are permitted on and along the trail. The raising of the recreational trail (where it would be crossed by the lower dam) would serve to maintain the trail's integrity and would ensure full public use of the trail and access to and across lands in the basin. We estimate that approximately $14,500 would be needed to provide for stone stairways on each of the dry dams ($11,500 for initial construction and $3,000 for annual operation and maintenance) and that $10,000 would be needed to elevate the recreational trail ($8,000 for initial construction and $2,000 for annual operation and maintenance). These costs should be funded as project costs and the recommended structures should be incorporated into the overall design, construction, operation, and maintenance plan for this project. Further, all Federal lands and waters in the project area should be open to the public for fish and wildlife related recreational uses.

The Batavia Reservoir Compound (modified) should be used as a model for future assessments of beneficial and adverse effects of irregularly flooded dry dam structures and of measures necessary to mitigate any adverse effects. Since no studies have ever been made of the effects of dry dams and their operation on aquatic and terrestrial ecosystems, such studies should be undertaken in association with this flood management project. Studies should be planned to collect biological data on both aquatic and terrestrial ecosystems prior to and during the construction phase of the project and on ecosystem conditions during a period of at least four years following project completion. In addition to its potential use in relation to other dry dam projects, this study could also provide information useful in mitigating the adverse effects of the Batavia Reservoir Compound (when completed) through procedures such as correcting the rate of outflow or lowering maximum floodpool elevations. We estimate that approximately $96,000 would be needed to fund studies necessary to determine:

1. The short-and long-term effects of irregular inundation on plant and animal community structure.

2. The degree of silting and sedimentation that can be expected from dry-dam operation and the effects of sedimentation on plant and animal communities.

3. The effects of dry-dams, dikes and outlet works on fish and wildlife movements in the area of project influence.

4. The effects of snag removal on the structure and functioning of the aquatic community and on public uses of the creek.

5. How reservoir outflow might be manipulated to achieve needed flood protection and to concurrently minimize the adverse effects of the project on fish and wildlife.

Prior to project construction, a plan of study should be developed by the Corps of Engineers in cooperation with and approved by the U. S. Fish and Wildlife Service and the New York State Department of Environmental Conservation. The estimated $96,000 needed to fund the studies should be applied for through the Corps of Engineers Research and Development Program.

AN ALTERNATIVE PLAN FOR FLOOD MANAGEMENT

Of the alternatives presented by your agency for flood management in the Tonawanda Creek watershed, the Batavia Reservoir Compound (unmodified plan) was selected by the Service as having the least potential adverse impact on fish and wildlife resources. We feel, however, that an additional alternative exists that has not previously been considered by your agency. This alternative would likely have fewer impacts on fish and wildlife and could actually enhance existing aquatic and terrestrial ecosystems. This alternative is a combination of both natural and managed flood control.

Existing bottomland habitats in the watershed have the potential for use as a system of natural flood control utilizing some management features. Under present conditions, many wet meadow, emergent marsh, shrub swamp, and forested wetland habitats are only seasonally flooded and during the course of spring and summer months they lose much standing water. These habitats would have greater intrinsic value to fish and wildlife if water levels were more stable. A diverse group of vertebrates, including many fish, amphibians, reptiles, waterfowl, herons, and furbearing mammals, would benefit from the stabilization of water levels, and fish and wildlife related recreational opportunities, including fishing, trapping, hunting, and bird-watching would be greatly improved.

Existing wetland habitats in the watershed could be modified with structures such as shallow levees with overflow outlet works that would retain floodwaters and maintain more seasonally stable water levels as well as increase flood storage capacity. Additional floodwater storage could be created in suitable areas through the construction of overflow diversion channels that would divert high flow water to some existing retention areas as well as to newly-created off-channel impoundments. These impoundments should be slow-draining with minimum-level conservation pools that would permit the development of aquatic and semi-aquatic plant associations. Off-channel impoundments, as opposed to the proposed dry-dams, would preserve the integrity of the Tonawanda Creek channel, as well as its ecology, and would provide needed floodwater storage, as well as create good fish and wildlife habitat.

Our proposal to use wetlands for floodwater storage is not a new concept, but even in the most ideal situation there is a need for man's assistance to promote natural watershed storage. For example, along the Charles River in Massachusetts, upper and middle watershed wetlands retain floodwaters and release them slowly, thereby lessening potential flooding problems in the lower reaches; but even so, many of the watershed's roadways have undersized culverts and bridge openings which turn the roadways into effective floodwater retention structures that increase the capacity and effectiveness of existing wetlands (U. S. Corps of Engineers, 1972). The Tonawanda Creek watershed has many wetlands whose flood retention capability could be enhanced and many non-wetland areas that could be developed into wetland/flood retention features of the ecosystem; however, such a plan would require the combined efforts and cooperation of engineers and biologists to formulate a managed/natural flood control plan for the Tonawanda Creek Watershed that is both engineeringly feasible and ecologically sound.

Since a managed/natural flood control plan would be an alternative to the Batavia Reservoir Compound (modified), all land and flowage easement purchases, and construction, and annual operation and maintenance costs should be funded as project costs. The lands and management structures could be administered by the New York State Department of Environmental Conservation under a mutually agreeable plan developed by the Corps of Engineers, the New York State Department of Environmental Conservation, and the U. S. Fish and Wildlife Service.

RECOMMENDATIONS

We recommend that:

1. A system of managed/natural flood control, as described herein, be given full consideration by your agency as a project alternative -- one that can potentially protect fish and wildlife resources and preserve ecosystem integrity, as well as provide the needed flood control in Tonawanda Creek Watershed. We further recommend that the managed/natural flood control alternative be developed through the combined efforts of the Corps of Engineers, the U. S. Fish and Wildlife Service, and the New York State Department of Environmental Conservation, and that if found feasible be implemented in lieu of the Batavia Reservoir Compound (modified).

2. The Batavia Reservoir Compound (modified), if constructed, be used as a model for future assessments of beneficial and adverse effects of irregularly flooded dry dam structures on aquatic and terrestrial ecosystems, and that the studies described herein be undertaken to provide the data base necessary for such assessments. We further recommend that, prior to project construction, a plan of study be developed by the Corps of Engineers in cooperation with and approved by the U. S. Fish and Wildlife Service and the New York State Department of Environmental Conservation, and that the estimated $96,000 needed to fund the studies be applied for through the Corps of Engineers Research and Development Program.

3. Prior to project construction, a plan be developed by the Corps of Engineers in cooperation with and approved by the New York State Department of Environmental Conservation, the U. S. Fish and Wildlife Service, the U. S. Soil Conservation Service, and the U. S. Environmental Protection Agency, to minimize the amount of project-caused erosion, siltation, and water pollution in Tonawanda Creek and its tributaries during and immediately after construction.

4. To mitigate the potentially adverse effects of the dry dams on normal fish movements in Tonawanda Creek, outlet works associated with the upper and lower dams be constructed in such a manner as to permit upstream-downstream fish passage during normal flow (non-flood) conditions. We further recommend that a plan detailing the provisions and/or facilities for fish passage through the outlet works be prepared by the Corps of Engineers in cooperation with and approved by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service, that all necessary structures be incorporated into the overall design, construction, operation, and maintenance plan for this project, and that they be provided at project cost.

5. All construction activities associated with instream or streambank areas, including snag removal, be restricted to the period from July 15 through November 15, when surface runoff and stream flow are generally lowest, and thus avoiding both the critical over-wintering period and the breeding season of many fish and wildlife species.

6. Prior to removal of snags from the creek and dead trees from along its banks, a plan be developed by the Corps of Engineers in cooperation with and approved by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service to minimize the adverse effects of these activities on fish and wildlife resources. We further recommend that the following provisions be included in the plan: (a) that stumps and logs embedded in the creek banks be cut rather than pulled, and that logs deeply embedded in the creek bottom be left undisturbed in order to maintain complexity and hence diversity in the aquatic ecosystem; (b) that large dead trees along the channel banks which are in no imminent danger of toppling into the creek be left standing to provide essential denning, nesting, resting, and feeding sites for wildlife; and (c) that streamside activities be avoided where mature riparian growth, particularly box-elder and willow, could be damaged.

7. Sections of Tonawanda Creek that are cut off or abandoned be plugged at their upstream and downstream ends with clean fill to provide conservation pools for fish and wildlife and that all riparian vegetation associated with these areas be left undisturbed.

8. Streambanks and upland areas surrounding the proposed dry dams and lateral dikes disturbed during construction activities as well as riparian areas disturbed during snag and dead tree removal, be revegetated as soon as possible after construction to mitigate the loss of wildlife habitat. We further recommend that prior to project construction, a revegetation plan be developed for the project in cooperation with and approved by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service, that the plan include the monitoring of growth conditions to ensure that revegetation is successful and the replacement of dead or dying plant species, and that all replanting, maintenance, and monitoring activities be funded as project costs.

9. To mitigate the potentially adverse effects of prolonged flooding on fish and wildlife and their habitats, that flood waters be retained in the reservoirs for the shortest period of time necessary to reduce downstream flood damages. We further recommend that prior to project constuction, operating criteria for flood water

retention and regulated release be established in cooperation with and approved by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service for the conservation and development of fish and wildlife resources, and that these criteria be adhered to by the Corps of Engineers as long as it exercises direct operational control of project features, and that any agreements entered into for the delegation or release of operational control to another agency include stipulations to prevent deviation from these criteria.

10. Valuable wetland complexes, located east of Creek Road and within the lower reservoir floodplool, be protected from complete inundation through the construction of lateral dikes with flap gates. We further recommend that the estimated $19,000 needed to provide protective structures ($15,500 for initial construction and $3,500 for annual operation and maintenance) be provided as a project cost and that all such structures be incorporated into the overall design, construction, operation, and maintenance plan for this project.

11. Project-caused Habitat Unit losses, including losses associated with upper reservoir wetlands, be compensated for through the purchase and management of habitat that is equivalent in wildlife value and located outside of the maximum floodpool boundary. We further recommend that the estimated $403,500 needed to purchase lands for compensation and $10,760 needed for annual management (operation and maintenance) of the lands be funded as project costs, that the management area be administered by the New York State Department of Environmental Conservation under a mutually agreeable plan developed by the Corps of Engineers, the New York State Department of Environmental Conservation, and the U. S. Fish and Wildlife Service, and that the report of the District Engineer, Corps of Engineers, include language calling specifically for Congressional authorization for the necessary land acquisition and management described herein.

12. Loss of public access to lands and waterways and of free movement across lands and along watercourses should be compensated for by providing (a) paths or stairways across the dams in the vicinity of the main creek channel, and (b) a sloping, earthen-fill ramp from the surface of the Batavia-Alexander Recreational Trail to the top of the lower dam where it crosses the trail. We further recommend that the estimated $40,000 needed to provide for stone stairways on each of the dry dams ($11,500 for initial construction and $3,000 for annual operation and maintenance) and for elevation of the recreational trail ($8,000 for initial construction and $2,000 for

annual operation and maintenance) be funded as a project cost and that these structures be incorporated into the overall design, construction, operation, and maintenance of the flood control project. Further, all Federal lands and waters in the project area should be open to the public for fish and wildlife related recreational uses.

13. All mitigation activities, including land purchases and fish and wildlife studies, be conducted under the auspices of an interagency monitoring team comprised of biologists from the Corps of Engineers, the U. S. Fish and Wildlife Service, and the New York State Department of Environmental Conservation, and that all of the activities of the monitoring team be funded as a project cost.

Please continue to coordinate this project with us as it develops, and advise us of any changes or additions to the project so that consideration may be given to revise or supplement this report.

Sincerely yours,

Paul P. Hamilton

Paul P. Hamilton
Field Supervisor

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Table 1. -- Fish species determined to be present in Tonawanda Creek and associated waters in the vicinity of the Towns of Alexander, Batavia, and Bethany, New York. A plus sign (+) denotes the observed presence of a species in a particular area or habitat type. Data are taken from unpublished fisheries survey reports provided by the State University of New York at Buffalo (left column) and Bio Systems Research, Inc., Buffalo, New York (right column; enclosed by parentheses).

	Tonawanda Creek[1] (upper)	Tonawanda Creek[2] (lower)	Little Tonawanda Creek	Other Tributary	Oxbow or Pond
Brown Trout	(-)	-(-)	-(+)	-(-)	-(-)
White Sucker	(+)	+(+)	+(+)	+(+)	-(+)
Northern Hog Sucker	(+)	+(+)	+(+)	+(-)	-(-)
Carp	(-)	-(-)	-(-)	-(-)	-(+)
Stoneroller	(+)	-(+)	+(+)	+(+)	-(-)
Blacknose Dace	(+)	-(-)	+(+)	+(+)	-(+)
Creek Chub	(+)	-(-)	+(+)	+(+)	-(+)
Hornyhead Chub	(+)	-(+)	+(+)	+(-)	-(-)
Fallfish	(+)	-(+)	+(+)	+(+)	-(+)
Golden Shiner	(+)	+(-)	-(-)	-(+)	+(+)
Bluntnose Minnow	(+)	-(+)	+(+)	+(+)	-(+)
Fathead Minnow	(-)	-(-)	-(-)	+(+)	-(+)
Common Shiner	(+)	-(+)	+(+)	+(+)	+(+)
River Shiner	(-)	-(-)	+(-)	-(-)	-(-)
Sand Shiner	(+)	-(-)	+(-)	-(-)	-(-)
Brown Bullhead	(+)	+(+)	+(-)	-(-)	-(+)
Central Mudminnow	(-)	-(-)	-(-)	-(-)	-(+)
Northern Pike	(+)	-(+)	-(+)	+(-)	-(+)
Yellow Perch	(+)	-(-)	-(-)	-(-)	+(+)
Logperch	(+)	-(+)	-(-)	-(-)	-(-)
Johnny Darter	(+)	-(+)	+(+)	+(+)	-(+)
Iowa Darter	(-)	-(-)	+(-)	-(-)	-(-)
Fantail Darter	(-)	-(-)	+(+)	+(+)	-(-)
Smallmouth Bass	(+)	+(+)	+(+)	-(-)	-(-)
Largemouth Bass	(+)	-(-)	-(-)	-(-)	+(-)
Green Sunfish	(-)	-(-)	-(+)	-(+)	-(+)
Pumpkinseed	(+)	+(-)	+(+)	+(-)	+(+)
Bluegill	(-)	-(-)	+(-)	+(-)	+(+)
Rock Bass	(+)	+(+)	+(+)	-(+)	+(+)

[1]Includes sampling conducted in the main channel between N.Y. Route 20 and Dorman Road. This area not sampled by SUNY-Buffalo.

[2]Includes sampling conducted in the main channel from the vicinity of Dorman Road to Main Street in the City of Batavia.

Table 2. -- Amphibians, reptiles, birds, and mammals and their associated habitats in the proposed Batavia Reservoir Compound and vicinity, Towns of Alexander and Batavia, New York. Data are summarized from field reconnaissance conducted between March 28 and July 13, 1979.

Species	Habitat										
	Tonawanda Creek	Tributary Stream	Pond or Wet Ditch	Emergent Marsh	Shrub Swamp	Forested Wetland	Riparian Hardwood	Railroad Right-of-Way	Hayfield or Pasture	Cropland	Residential
Amphibians											
Wood Frog			X		X	X				X	
Northern Leopard Frog		X	X	X	X						
Bullfrog		X	X	X			X				
Green Frog		X	X	X	X	X	X	X	X		
Gray Tree Frog				X	X	X					
Spring Peeper				X	X	X					
Western Chorus Frog				X							
American Toad	X			X	X	X	X	X	X	X	
Blue-spotted Salamander			X			X		X			
Jefferson's Salamander								X			
Reptiles											
Eastern Milk Snake											X
Northern Water Snake			X	X				X			
Eastern Garter Snake		X				X	X	X	X		X
Northern Ribbon Snake								X	X		
Northern Brown Snake								X	X		
Northern Red-bellied Snake								X	X		
Common Snapping Turtle			X	X	X	X	X	X	X		
Midland Painted Turtle			X	X		X		X		X	
Wood Turtle								X			
Birds											
Great Blue Heron*			X	X		X	X		X		
Great Egret*				X							
Green Heron			X	X	X	X		X			
American Bittern									X		
Canada Goose	X		X	X		X			X		X
Wood Duck				X		X	X				
Mallard	X	X		X	X	X	X		X	X	X

Table 2 (Continued).

Species	Habitat										
	Tonawanda Creek	Tributary Stream	Pond or Wet Ditch	Emergent Marsh	Shrub Swamp	Forested Wetland	Riparian Hardwood	Railroad Right-of-Way	Hayfield or Pasture	Cropland	Residential
American Widgeon*				X		X					
Blue Winged Teal			X	X							
Turkey Vulture						X			X	X	
Red-tailed Hawk						X	X		X		
Marsh Hawk**									X		
American Kestrel					X				X	X	
Ring-necked Pheasant										X	X
Wild Turkey						X					
Common Gallinule				X							
Killdeer	X			X			X	X	X	X	X
American Woodcock						X		X			
Common Snipe				X					X		
Greater Yellowlegs**				X						X	
Spotted Sandpiper**	X		X	X			X				
Herring Gull**									X		
Black Tern**				X							
Rock Dove							X		X	X	X
Mourning Dove					X	X	X	X	X	X	X
Black-billed Cuckoo					X			X			X
Great Horned Owl							X				
Common Nighthawk											X
Chimney Swift									X	X	X
Belted Kingfisher			X	X		X	X		X		
Common Flicker				X	X	X	X	X	X		X
Red-bellied Woodpecker						X					
Red-headed Woodpecker						X	X				X
Hairy Woodpecker						X	X				
Downy Woodpecker							X				
Eastern Kingbird				X	X				X	X	
Great Crested Flycatcher						X	X				
Eastern Phoebe					X	X		X			
Least Flycatcher						X	X				
Eastern Wood Pewee						X	X	X			
Horned Lark									X	X	
Tree Swallow				X							
Barn Swallow			X	X		X	X		X	X	X

Table 2 (Continued).

Species	Tonawanda Creek	Tributary Stream	Pond or Wet Ditch	Emergent Marsh	Shrub Swamp	Forested Wetland	Riparian Hardwood	Railroad Right-of-Way	Hayfield or Pasture	Cropland	Residential
Blue Jay					X	X	X		X		X
American Crow						X	X	X	X	X	
Black-capped Chickadee					X	X	X				
White-breasted Nuthatch					X	X	X				
House Wren						X	X				
Gray Catbird				X	X	X	X	X			
Brown Thrasher**						X					
American Robin					X	X	X	X	X	X	X
Wood Thrush						X	X	X			
Veery					X	X					
Cedar Waxwing					X		X	X			
Red-eyed Vireo						X	X				
Warbling Vireo						X	X				
Yellow Warbler					X	X	X	X			X
Common Yellowthroat				X	X	X	X	X			
Yellow-rumped Warbler**						X					
Blue-winged Warbler**						X					
Bobolink				X					X		
Eastern Meadowlark									X		
Red-winged Blackbird				X	X	X	X	X	X	X	X
Northern Oriole						X	X	X			
Common Grackle				X	X	X	X		X	X	X
Brown-headed Cowbird					X	X	X			X	X
Rusty Blackbird**						X					
Common Starling											X
House Sparrow										X	X
Scarlet Tanager						X	X				
Common Cardinal					X	X	X	X			X
Rose-breasted Grosbeak						X	X	X			
Indigo Bunting						X	X				
American Goldfinch					X	X	X	X	X	X	
Rufous-sided Towhee**							X				
Savannah Sparrow									X	X	
Henslow's Sparrow				X							
Vesper Sparrow									X	X	
Chipping Sparrow					X						X

Table 2 (Continued).

Species	Tonawanda Creek	Tributary Stream	Pond or Wet Ditch	Emergent Marsh	Shrub Swamp	Forested Wetland	Riparian Hardwood	Railroad Right-of-Way	Hayfield or Pasture	Cropland	Residential
						Habitat					
Field Sparrow					X		X		X		
Slate-colored Junco**											
White-throated Sparrow**					X		X	X			
Swamp Sparrow				X	X						
Song Sparrow					X	X	X	X		X	
House Finch											X
Mammals											
Opossum	X					X			X	X	
Masked Shrew							X				
Short-tailed Shrew			X	X	X		X	X	X		
Eastern Cottontail Rabbit					X	X		X			
Eastern Chipmunk					X	X	X	X		X	X
Woodchuck					X	X	X	X	X		
Eastern Gray Squirrel						X		X			X
Red Squirrel						X					X
Deer Mouse						X	X				
White-footed Mouse						X					
Muskrat		X	X	X	X			X			
Meadow Jumping Mouse							X				
Raccoon	X		X			X	X		X		
Mink							X				
Striped Skunk					X	X	X		X	X	
White-tailed Deer	X		X	X	X	X	X	X	X	X	

* Non-breeding spring resident.
** Spring migrant.

Table 3. -- Results of 1979 breeding bird censuses taken along stands of riparian growth on Tonawanda Creek, Towns of Alexander and Batavia, New York. Numbers indicate counts of singing birds.

	Dates/Transect #1[a]			Dates/Transect #2[b]		
Species	6-6-79	6-27-79	7-11-79	6-6-79	6-27-79	7-11-79
Yellow Warbler	17	10	9	11	12	4
Red-winged Blackbird	10	7	7	0	2	1
Song Sparrow	8	10	12	3	10	9
House Wren	6	5	7	6	7	6
American Robin	5	6	8	5	4	3
Brown-headed Cowbird	0	0	3	4	4	4
Gray Catbird	2	4	3	1	2	4
Common Cardinal	2	0	1	0	1	0
Rose-breasted Grosbeak	2	0	1	0	0	0
Eastern Wood Pewee	0	2	2	1	0	1
Least Flycatcher	1	0	2	2	0	1
Red-headed Woodpecker	0	0	0	2	0	0
White-breasted Nuthatch	1	0	1	0	0	2
American Goldfinch	1	1	3	0	1	3
Common Grackle	1	1	0	0	0	0
Spotted Sandpiper	0	1	0	1	1	0
Mourning Dove	1	1	0	0	0	0
Great Crested Flycatcher	1	0	0	0	0	0
Wood Thrush	1	0	0	0	0	0
Mallard	1	0	0	0	0	0
Warbling Vireo	0	1	1	0	0	0
Northern Oriole	0	1	0	0	1	0
Downy Woodpecker	0	1	0	0	0	0
Belted Kingfisher	0	0	1	0	0	0
Red-eyed Vireo	0	0	1	0	0	0
Common Yellowthroat	0	0	1	0	0	0
Indigo Bunting	0	0	0	0	0	1

[a] Transect #1 ran 1,295 meters north along Tonawanda Creek from Peaviner Road.

[b] Transect #2 ran 1,029 meters northeast along Tonawanda Creek from where the creek intersects the Erie Railroad embankment.

Table 4. -- Evaluation elements (species) used to evaluate wildlife habitat in the area of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York.

Evaluation Element (Species)	Habitat Types				
	Emergent Marsh	Shrub Swamp	Forested Wetland	Pasture	Cropland
Amphibians					
Wood Frog (*Rana sylvatica*)			X		
Blue-spotted Salamander (*Ambystoma laterale*)			X		
Reptiles					
Eastern Garter Snake (*Thamnophis sirtalis*)					X
Birds					
Indigo Bunting (*Passerina cyanea*)		X			
Eastern Meadowlark (*Sturnella magna*)				X	
Red-winged Blackbird (*Agelaius phoeniceus*)	X				
Horned Lark (*Eremophila alpestris*)					X
Spotted Sandpiper (*Actitis macularia*)	X				
Belted Kingfisher (*Megaceryle alcyon*)			X		
Kestrel (*Falco sparverius*)				X	X
Mammals					
Meadow Vole (*Microtus pennsylvanicus*)	X	X			
Eastern Cottontail Rabbit (*Sylvilagus floridanus*)		X			
Red Fox (*Vulpes vulpes*)				X	
White-tailed Deer (*Odocoileus Virginianus*)		X	X	X	X
Total Species 14	3	4	4	4	4

Table 5. -- Inventory characteristics used to evaluate wildlife habitat in the area of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York.

	Habitat Types				
Inventory Characteristics	Emergent Marsh	Shrub Swamp	Forested Wetland	Pasture	Cropland
% Herbaceous Ground Cover	X	X		X	X
% Shrub Crown Cover		X		X	
% Tree Canopy Closure			X		
Composition of Vegetation	X	X		X	
Type of Rowcrop					X
No. of Browse Species Present/Acre			X		
Av. Height of Herbaceous Vegetation	X	X		X	X
Av. Height of Shrubs		X			
Av. Height of Trees			X		
% Treeland within 1Km Radius					X
Distance to Woodland or Brushy Cover		X		X	X
Distance to Cutbanks for Nesting			X		
Distance to Feeding Area			X		
Distance to Water	X	X		X	X
Abundance of Water Bodies			X		
Water Depth	X		X		
Abundance of Dead Logs, Stumps, Etc.			X		
Depth of Leaf Litter			X		
% Forest Floor Covered by Leaf Litter			X		
% Pool Bottom Covered by Plant Debris			X		
Soil Type				X	
Relative Soil Moisture	X	X	X		X
Consecutive Days of Snow Cover				X	X
Abundance of Perch Sites		X	X	X	X
Abundance of Nest Cavities or Boxes				X	X

Table 6. -- Summary of baseline habitat conditions in the area of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York.

Habitat Type	HSI[1]	Habitat Units[2] (Number of Hectares)		
		Upper Pool	Lower Pool	Total
Emergent Marsh (EM)	0.664	29.0(43.7)	23.9(36.0)	52.9(79.7)
Shrub Swamp (SS)	0.750	38.0(50.6)	96.9(129.2)	134.9(179.8)
Forested Wetland (FO)	0.803	63.7(79.4)	295.0(367.3)	358.7(446.7)
Pasture (P)	0.754	28.1(37.3)	98.6(130.8)	126.7(168.1)
Cropland (C)[3]	0.605	75.5(124.7)	256.8(424.4)	332.3(549.1)
Total	-----	234.3(335.7)	771.2(1087.7)	1005.5(1423.4)

[1]Habitat Suitability Index.

[2]Habitat Unit=HSIX hectares.

[3]Includes hayfields.

Table 7. -- Estimated loss of Habitat Units due to the construction of dry dams and lateral dikes for the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York.

Flood Management Structures	Habitat Units (Number of Hectares)					
	Emergent Marsh	Shrub Swamp	Forested Wetland	Pasture	Cropland	Totals
Lower Dam	0.0(0.0)	-1.3(1.7)	-1.2(0.3)	0.0(0.0)	-3.0(5.0)	-4.5(6.9)
Upper Dam	-0.7(1.0)	0.0(0.0)	-0.3(0.4)	0.0(0.0)	-2.2(3.6)	-3.2(5.0)
Lateral Dikes	0.0(0.0)	-0.1(0.1)	-0.1(0.2)	0.0(0.0)	-1.4(2.3)	-2.6(2.6)
Totals	-0.7(1.0)	-1.4(1.8)	-0.7(0.8)	0.0(0.0)	-6.5(10.8)	-9.2(14.4)

Table 8. -- Annualized Habitat Unit changes for without-the-project conditions and within the flood pool boundaries of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York.

		Upper Reservoir Pool			Lower Reservoir Pool			
Habitat Type (HSI)[1]	Target Year	Hectares	Habitat Units	Annualized Habitat Unit Change	Hectares	Habitat Units	Annualized Habitat Unit Change	Total Annualized Habitat Unit Change
Emergent Marsh								
(0.664)	0	43.7	29.0		36.0	23.9	0.0	0.0
	25	43.7	29.0		36.0	23.9		
	50	43.7	29.0		36.0	23.9		
	75	43.7	29.0		36.0	23.9		
	100	43.7	29.0	0.0	36.0	23.9	0.0	0.0
Shrub Swamp								
(0.750)	0	50.6	38.0		129.2	96.9		
	25	43.4	32.5		106.6	79.9		
	50	36.3	27.2		84.1	63.1		
	75	29.1	21.8		61.5	46.1		
	100	22.0	16.5	-27.2	38.9	29.2	-63.0	-90.2
Forested Wetland								
(0.803)	0	79.4	63.7		367.3	295.0		
	25	88.9	71.4		393.1	315.7		
	50	98.4	79.0		419.0	336.5		
	75	107.9	86.6		444.8	357.2		
	100	117.3	94.2	+79.0	470.7	378.0	+337.2	+416.2
Pasture								
(0.754)	0	37.3	28.1		130.8	98.6		
	25	35.0	26.4		127.5	96.1		
	50	32.6	24.6		124.3	93.7		
	75	30.3	22.8		121.0	91.2		
	100	28.0	21.1	-24.6	117.7	88.7	-93.7	-118.3
Cropland								
(0.605)	0	124.7	75.5		424.4	256.8		
	25	124.7	75.5		424.4	256.8		
	50	124.7	75.5		424.4	256.8		
	75	124.7	75.5		424.4	256.8		
	100	124.7	75.5	0.0	424.4	256.8	0.0	0.0
Total Annualized Habitat Unit Change				+27.2			+180.5	+207.7

[1]Habitat Suitability Index.

Table 9. -- Annualized Habitat Unit changes for with-the-project conditions and within the flood pool boundaries of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York.

Habitat Type (HSI)[1]	Target Year	Upper Reservoir Pool Hectares	Upper Reservoir Pool Habitat Units	Upper Reservoir Pool Annualized Habitat Unit Change	Lower Reservoir Pool Hectares	Lower Reservoir Pool Habitat Units	Lower Reservoir Pool Annualized Habitat Unit Change	Total Annualized Habitat Unit Change
Emergent Marsh								
(0.664)	0	43.7	29.0		36.0	23.9		
	25	44.1	29.3		48.5	32.2		
	50	59.8	39.7		60.9	40.4		
	75	75.5	50.1		73.4	48.7		
	100	91.2	60.6	+41.0	85.8	57.0	+40.5	+81.5
Shrub Swamp								
(0.750)	0	50.6	38.0		129.2	96.9		
	25	32.0	24.0		121.3	91.0		
	50	31.0	23.2		120.0	90.0		
	75	30.1	22.6		118.6	88.9		
	100	29.2	21.8	-24.9	117.3	88.0	-90.6	-115.5
Forested Wetland								
(0.803)	0	79.4	63.7		367.3	295.0		
	25	54.0	43.4		365.6	293.6		
	50	56.3	45.2		382.2	306.9		
	75	58.7	47.1		398.9	320.3		
	100	61.0	49.0	-48.0	415.5	333.7	+308.8	+260.8
Pasture								
(0.754)	0	37.3	28.1		130.8	98.6		
	25	19.6	14.8		117.0	88.2		
	50	14.9	11.2		110.4	83.2		
	75	10.3	7.8		103.9	78.3		
	100	5.6	4.2	-12.5	97.3	73.4	-83.9	-96.4
Cropland								
(0.605)	0	124.7	75.5		424.4	256.8		
	25	37.4	22.6		382.0	231.1		
	50	24.9	18.8		360.7	218.2		
	75	12.5	9.4		339.5	205.4		
	100	0.0	0.0	-20.7	318.3	192.6	-219.8	-240.5
Total Annualized Habitat Unit Change				-65.1			-45.0	-110.1

[1]Habitat Suitability Index.

Table 10. -- Average annual change in Habitat Units within the flood pool boundaries of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, New York, and area required for in-kind compensation of Habitat Unit losses.

Habitat Types	Average Annual Change in Habitat Units[1]		Net Average[2] Annual Change HU's	Area Required for Compensation (Hectares)
	Without the Project	With the Project		
Emergent Marsh	0.0	+81.5	+81.5	0.0
Shrub Swamp	-90.2	-115.5	+25.3	33.7
Forested Wetland	+416.2	+260.8	-155.4	193.5
Pasture	-118.3	-96.4	+21.9	0.0
Cropland	0.0	-240.5	-240.5	397.5
Total	+207.7	-110.1	-317.8	624.7

[1]Average annual change in Habitat Units from Tables 8 and 9.

[2]Does not include Habitat Units lost due to the construction of the dry dams and lateral dikes (Table 7).

Table 11. -- Relative Importance Value Criteria determined for each habitat type in the area of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, Genesee County, New York.

RIV Criteria	Range of Value[1]	Habitat Type: Emergent Marsh	Shrub Swamp	Forested Wetland	Pasture	Cropland
Abundance	1-most abundant 10-least abundant	10	8	3	8	1
Vulnerability	1-lowest probability 10-greatest probability	6	1	1	9	10
Replaceability	1-easily managed and/or created 10-little or no possibility to manage or create	5	8	10	2	1
Aesthetic Value	1-lowest value 10-highest value	9	5	10	3	1
Recreational Diversity	1-low 10-high	10	7	10	2	2
Species Richness	1-lowest 10-highest	7	8	10	3	1

[1] A scale of 1-10 was used for filling each square of this matrix.

Table 12. --Pairwise comparison of Relative Importance Value Criteria, and weighting factors used in the development of Relative Importance Values.

RIV Criteria	Pairwise Comparisons[1]																					Sum	Weight[2]
Abundance	1	1	1	0	0	1																4	0.19
Vulnerability	0						1	1	1	0	1											4	0.19
Replaceability		0					0					1	1	0	1							3	0.14
Aesthetic Value			0					0				0				0	0	1				1	0.05
Recreational Diversity				1					0				0			1			0	1		3	0.14
Species Richness					1					1				1					1		1	6	0.29
Dummy Variables						0					0				0			0		0	0	0	0.00
Total																						21	1.00

[1]This technique requires that each criterion be compared to every other criterion, and a decision made as to which criterion of any pair is the most significant. A *dummy* criterion is included to insure that all criteria will have some weighting value.

[2]The sum total is divided into each criterion sum and the resulting value entered in the weight column representing the relative importance of each criterion.

Table 13. -- Relative Importance Values determined for each habitat type in the area of the proposed Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, Genesee County, New York.

RIV Criteria	Habitat Types				
	Emergent Marsh	Shrub Swamp	Forested Wetland	Pasture	Cropland
Abundance	1.90[1]	1.52	0.57	1.52	0.19
Vulnerability	1.14	0.19	0.19	1.71	1.90
Replaceability	0.70	1.12	1.40	0.28	0.14
Aesthetic Value	0.45	0.25	0.50	0.15	0.05
Recreational Diversity	1.40	0.98	1.40	0.28	0.28
Species Richness	2.03	2.32	2.90	0.87	0.29
Total	7.62	6.38	6.96	4.81	2.85
Relative Importance Value (RIV)[2]	1.00	0.84	0.91	0.63	0.37

[1]Represents the product of the values from Tables 11 and 12.

[2]The Relative Importance Value is obtained by dividing the sum for each habitat type by the greatest individual sum.

Table 14. -- Adjustment of Habitat Unit losses and gains using Relative Importance Values, and areas required for compensation of Habitat Unit losses expected from the construction and operation of the Tonawanda Creek Flood Control Project, Town of Alexander and Batavia, Genesee County, New York.

Habitat Type	RIV[1]	Net Gain or loss of HU's[2]	RIV Habitat Type 1 / RIV Habitat Type 2		HU's Type 2 / HV's Type 1	X HU's	Adjusted HU's	Area Required for compensation (Hectares)
Pasture (A)	0.63	+21.9				-21.9	0.0	0.0
Cropland (B)	0.37	-247.0	$\frac{0.63(A)}{0.37(B)}$	=	$\frac{X(B)}{21.9(A)}$	+37.3	-209.7	---
Emergent Marsh (C)	1.00	+80.8				-80.8	0.0	0.0
Cropland (B1)	0.37	-209.7	$\frac{1.00(C)}{0.37(B1)}$	=	$\frac{X(B1)}{80.8(C)}$	+218.4	+8.7	---
Cropland (B2)	0.37	+4.3[3]				-4.3	0.0	0.0
Shrub Swamp (D)	0.84	-25.4	$\frac{0.37(B2)}{0.84(D)}$	=	$\frac{X(D)}{4.3(B2)}$	+1.9	-23.5	31.4
Cropland (B3)	0.37	+4.3[3]				-4.3	0.0	0.0
Forested Wetland(E)	0.91	-156.1	$\frac{0.37(B3)}{0.91(E)}$	=	$\frac{X(E)}{4.3(B3)}$	+1.7	-154.4	192.3
Total adjusted area required for compensation								223.7

[1]Relative Importance Values from Table 13.

[2]Includes Habitat Unit losses from the construction of dry dams and lateral dikes (Table 7).

[3]Habitat Unit losses in cropland habitat (B1) are distributed evenly among shrub swamp and forested wetland for compensation purposes.

Table 15. -- Estimated costs for the acquisition and the operation and maintenance of wildlife habitat needed (a) to compensate for Habitat Unit losses and (b) for the in-kind replacement of upper reservoir floodpool wetlands, Tonawanda Creek Flood Control Project, Towns of Alexander and Batavia, Genesee County, New York.

Habitat Types	Number[1] of Hectares	Acquisitions Costs[2,3]		Operation and Maintenance Costs[3,4]	
		Cost/Hectare	Total Cost	Cost/Hectare	Total Cost
Emergent Marsh	15.1	$1,500	$22,650	$40	$604
Shrub Swamp	61.6	$1,500	$92,400	$40	$2,464
Forested Wetland	192.3	$1,500	$288,450	$40	$7,692
Pasture	0.0	-----	-------	---	-------
Cropland	0.0	-----	-------	---	-------
Totals			$403,500		$10,760

[1]Sum of areas shown in Table 14 and areas required for in-kind replacement of the 45.2 ha wetland complex in the upper-reservoir floodpool.

[2]Land acquisition costs estimated by the Corps of Engineers, Buffalo District, based on 1980 dollars.

[3]Field costs estimated by the New York State Department of Environmental Conservation and the U. S. Fish and Wildlife Service based on 1980 dollars.

[4]Annualized cost over period of analysis (100 years).

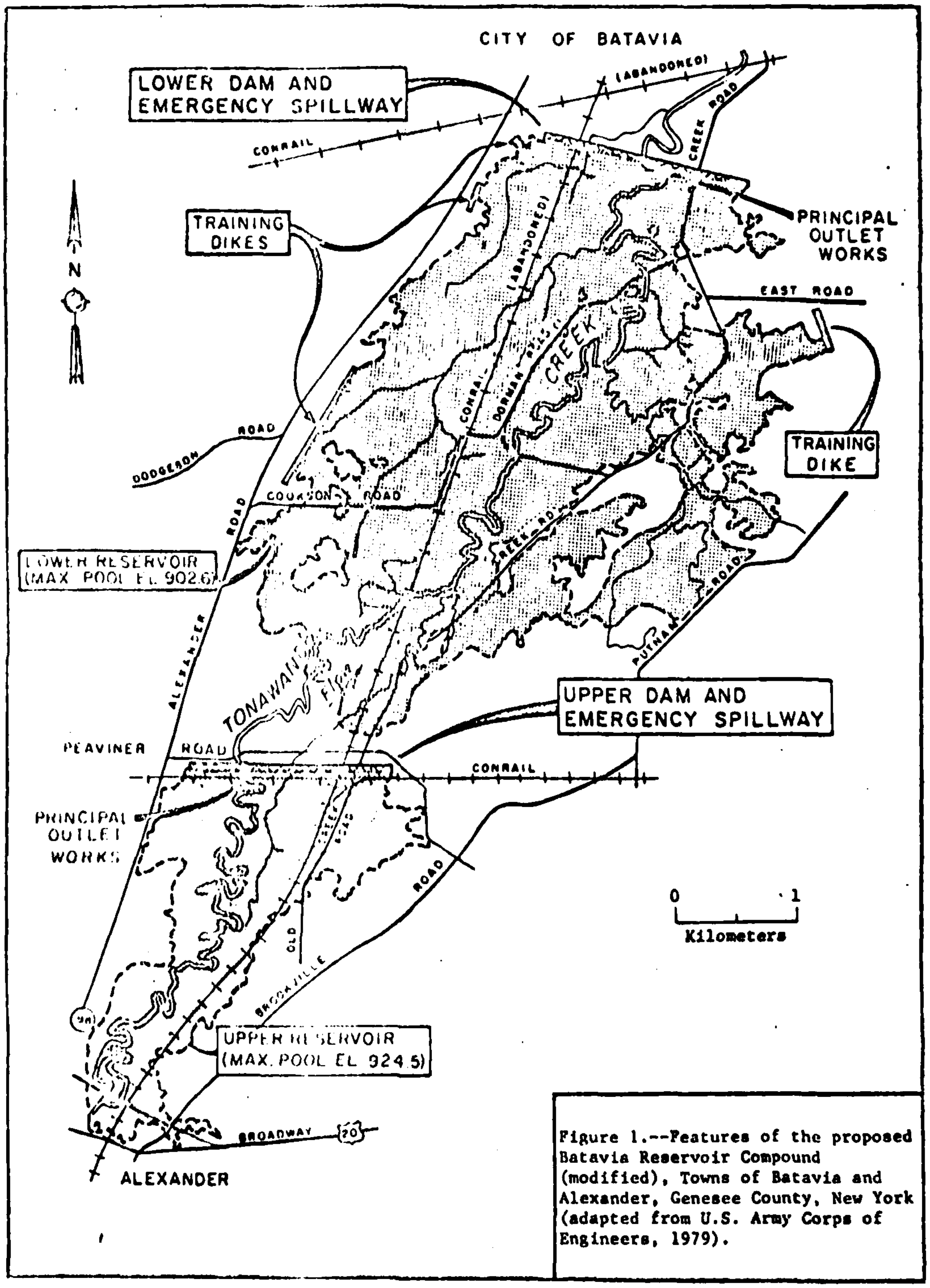

Figure 1.--Features of the proposed Batavia Reservoir Compound (modified), Towns of Batavia and Alexander, Genesee County, New York (adapted from U.S. Army Corps of Engineers, 1979).

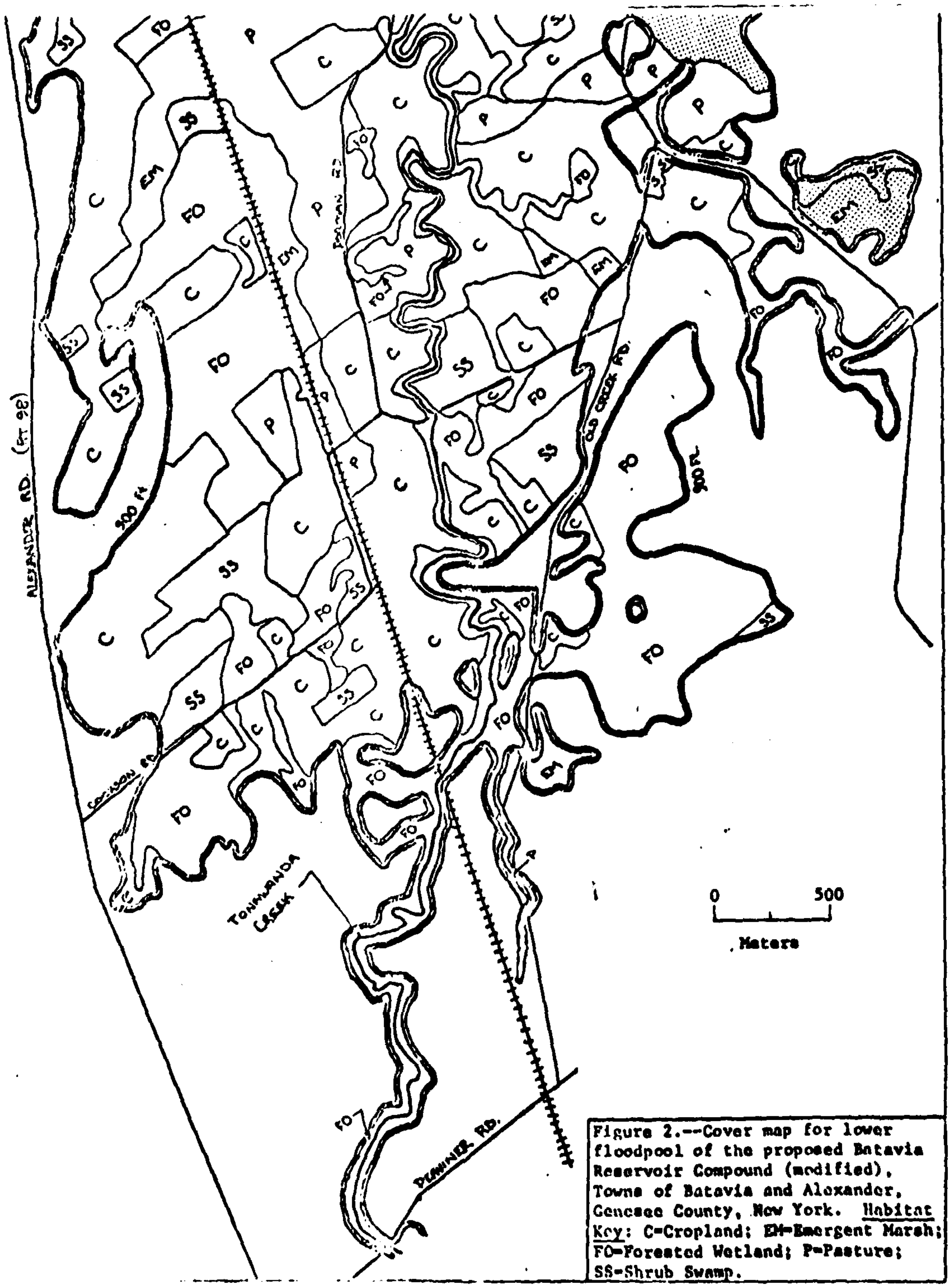

Figure 2.--Cover map for lower floodpool of the proposed Batavia Reservoir Compound (modified), Towns of Batavia and Alexander, Genesee County, New York. Habitat Key: C=Cropland; EM=Emergent Marsh; FO=Forested Wetland; P=Pasture; SS=Shrub Swamp.

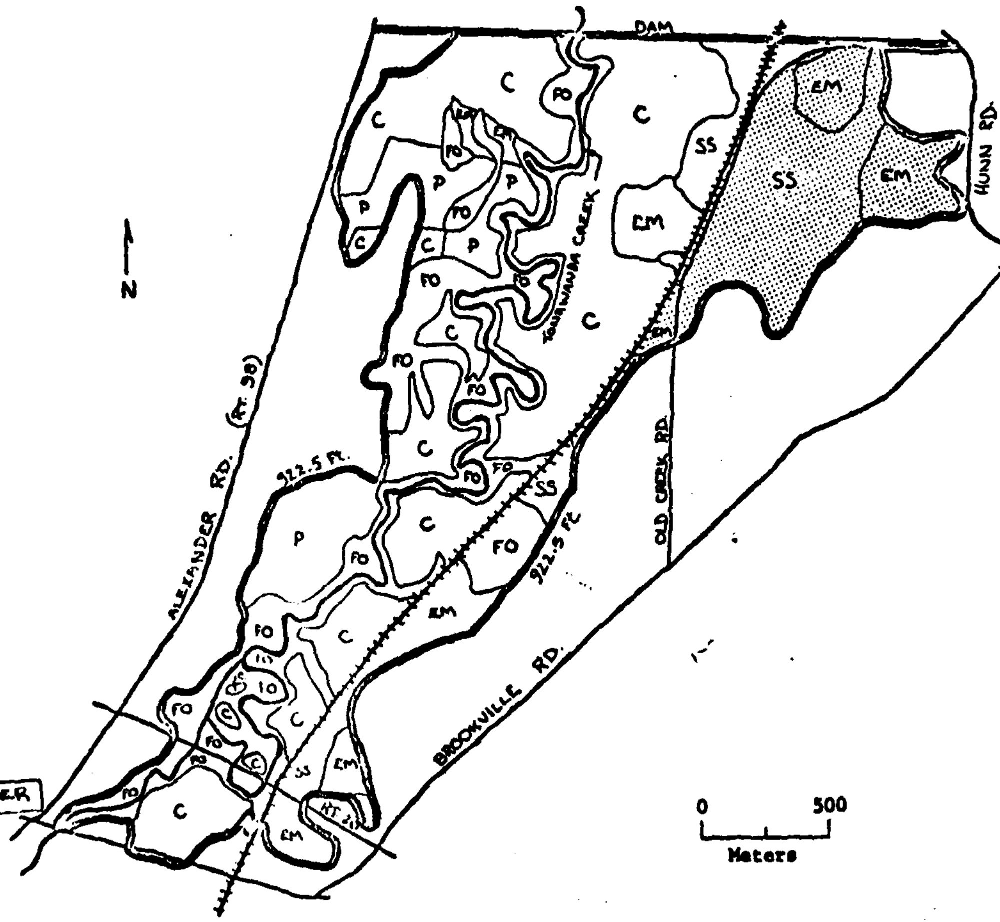

Figure 3.--Cover map for upper floodpool of the proposed Batavia Reservoir Compound (modified), Towns of Batavia and Alexander, Genesee County, New York. Habitat Key: C=Cropland; EM=Emergent Marsh; FO=Forested Wetland; P=Pasture; SS=Shrub Swamp.

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Robert F. Flacke
Commissioner

February 20, 1980

Mr. Paul P. Hamilton
Field Supervisor
United States Department of
the Interior
Fish and Wildlife Service
100 Grange Place, Room 202
Cortland, New York 13045

Dear Mr. Hamilton:

The Division of Fish and Wildlife is in general accord with the findings and recommendations of the report on the proposed flood control project along Tonawanda Creek in the towns of Batavia and Alexander, Genesee County, New York. But we do feel that instead of using the term "selective snagging", you should indicate that stumps embedded in the bank should be cut rather than pulled, and where they would not materially affect the roughness of the bottom, deeply embedded logs are to remain in the bottom. We also believe that instead of building a stairway or path traversing the dams, the Batavia-Alexander Recreational Trail should be re-routed around the structures.

Sincerely,

Kenneth Wich

Kennth F. Wich
Director
Division of Fish and Wildlife

cc: James Kelley

New York State Department of Environmental Conservation
6274 E. Avon-Lima Rd. Avon, New York 14414

Robert F. Flacke
Commissioner

Eric A. Seiffer
Regional Director

September 29, 1980

Mr. Paul B. Hamilton
Field Supervisor
United States Department of the Interior
Fish and Wildlife Service
100 Grange Place, Room 202
Cortland, New York 13045

Dear Mr. Hamilton:

The Division of Fish and Wildlife concurs with the findings and recommendations of the report on the Corps of Engineers Tonawanda Creek Flood Control Project, Towns of Batavia and Alexander, Genesee County, New York prepared under the authority of the Fish and Wildlife Coordination Act (16 USC 661).

We would also like to make some specific recommendations for sites to be considered as mitigation (see attached).

Site #1 - Shallow fresh marsh, deep fresh marsh, wood wetland, gets heavy use by waterfowl and heavy hunting pressure; great potential for enhancement with water control structures.

Sites #2 and #3 - High vulnerability to filling for industrial development, shallow fresh marsh, wooded swamp, has good potential for enhancement.

Sites #4 and 5 - Wooded swamp, low potential for enhancement.

Sites #7, 7 and 8 - Shallow fresh to deep fresh marsh, good potential for enhancement.

If you have any questions concerning these areas, please contact Jack Cooper or Dan Carroll at our Regional Office. Our continued coordination on this project should help to ensure an environmentally acceptable project.

Very truly yours,

Edward D. Holmes

Edward D. Holmes
Regional Supervisor
Fish & Wildlife
Region #8

Kenneth Wich

Kenneth Wich
Director
Division of Fish & Wildlife

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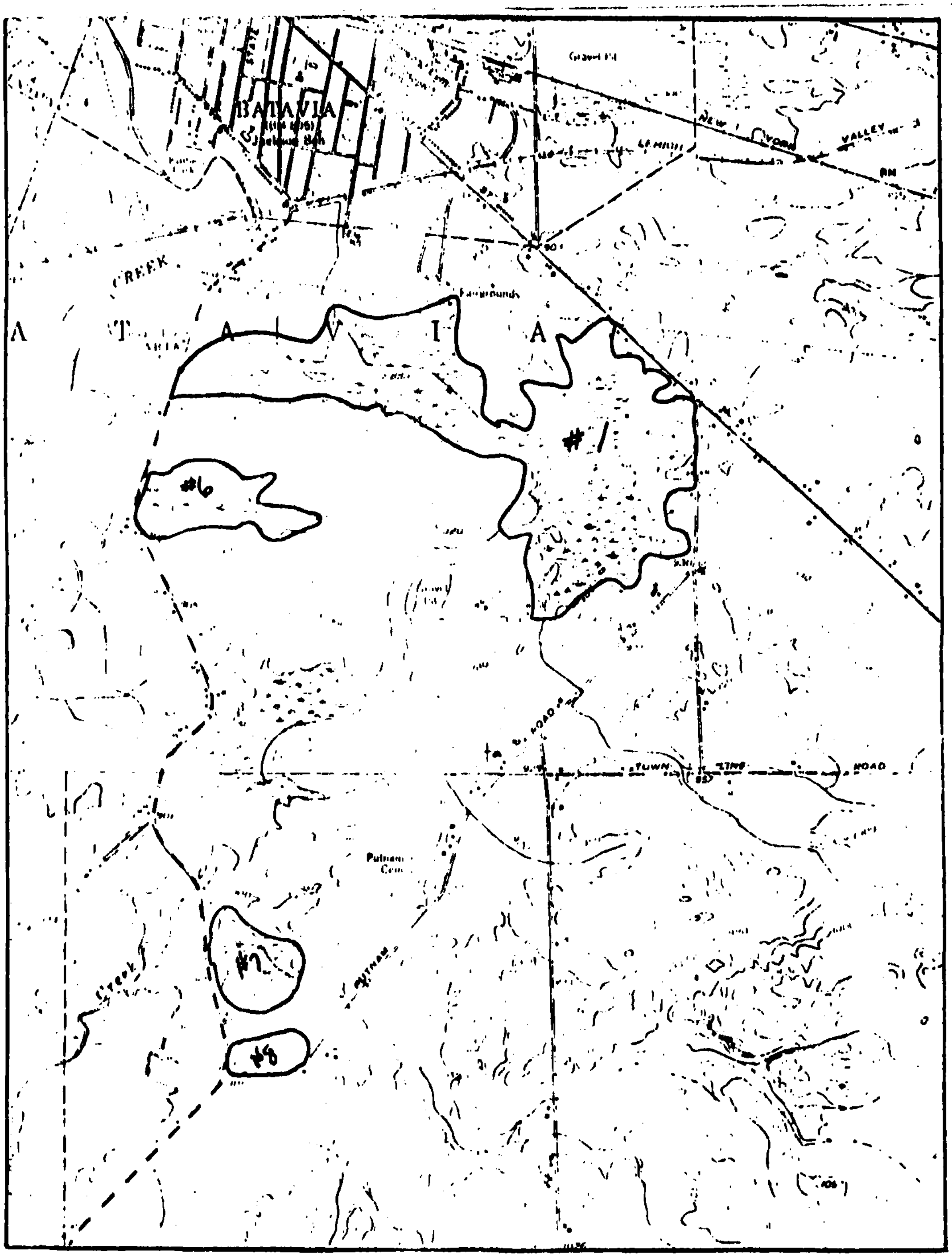
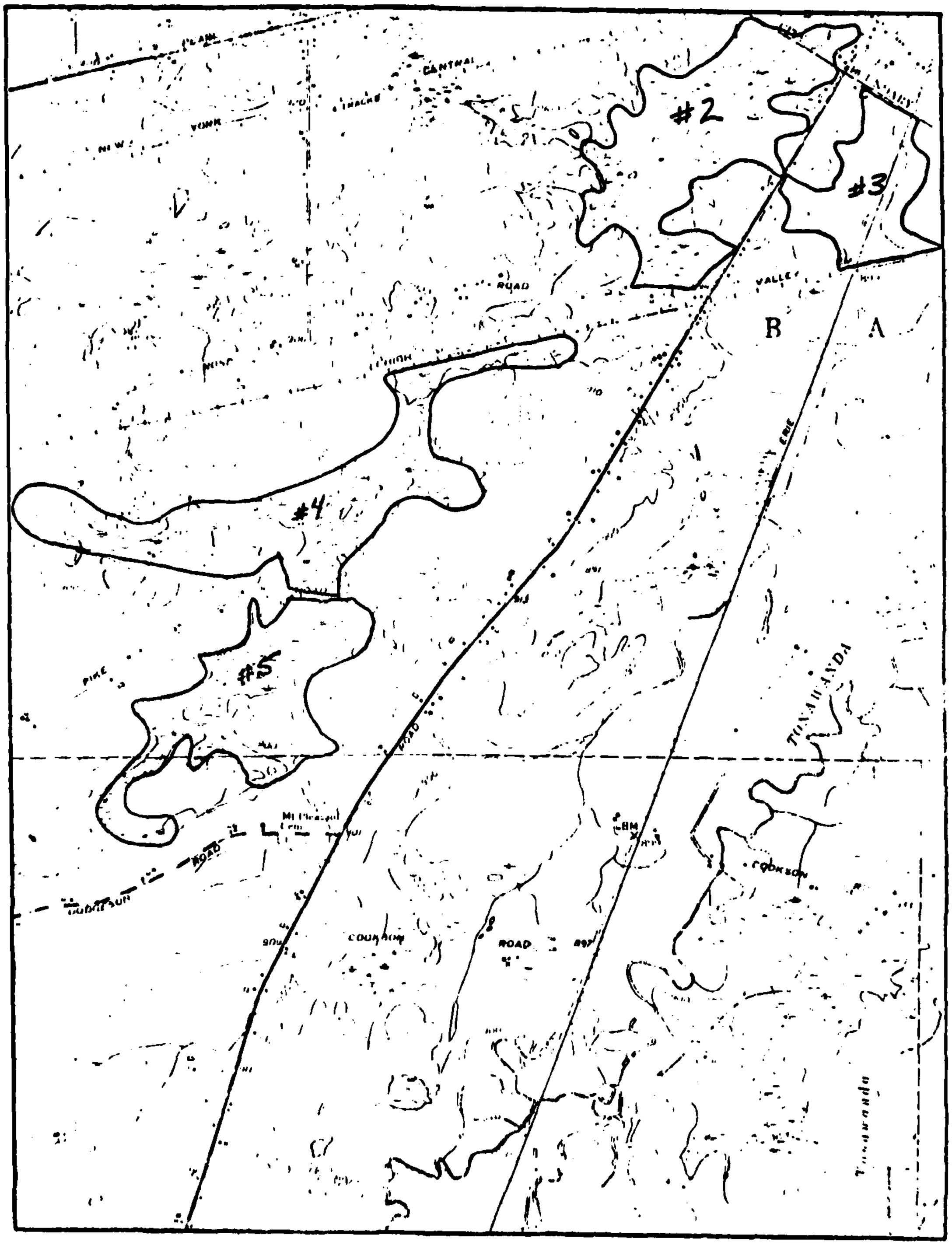


USGS 7.5' Quad, Batavia South, 1950



USGS 7.5' Quad, Batavia South, 1950

NCBED-PE 17 October 1980

Dr. Bennie Keel
Departmental Consulting Archaeologist
Heritage Conservation and
Recreation Service
U. S. Department of the Interior
Washington, DC 20243

Dear Dr. Keel:

Enclosed for your information is a Final Cultural Resources Report entitled, Batavia Reservoir Compound: Phase I Archaeological Summary and Appendicies.

If you have any questions regarding this report, please contact Mr. Richard H. Lewis, Staff Archaeologist, at (716) 876-5454, extension 2175.

Sincerely,

2 Incl
as stated

DONALD M. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis____
Berkeley____
Bennett____
Pieczynski____
Hallock____
Liddell____

NCBED-PE 17 October 1980

Mrs. Myra Harrison
Division of Archaeology
Heritage Conservation and
Recreation Service
William J. Green Federal Building
600 Arch Street
Room 9310
Philadelphia, PA 19106

Dear Ms. Harrison:

Enclosed for your information is a Final Cultural Resources Report entitled, Batavia Reservoir Compound: Phase I Archaeological Summary and Appendicies.

If you have any questions regarding this report, please contact Mr. Richard H. Lewis, Staff Archaeologist, at (716) 876-5454, extension 2175.

Sincerely,

2 Incl
as stated

DONALD M. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis
Berkeley
Bennett
Pieczynski
Hallock
Liddell

NCBED-PE 17 October 1980

SUBJECT: Transmittal of the Batavia Reservoir Compound: Phase I Archaeological Summary

THRU: Division Engineer, North Central
ATTN: NCDPD-ER

TO: HQDA (DAEN-ASI-L)
WASH, DC 20413

1. References: ER 1105-2-460, Identification and Administration of Cultural Resources.

2. The subject report and appendicies are transmitted in accordance with paragraph 460.14(d) of the referenced regulation.

FOR THE DISTRICT ENGINEER:

2 Incl
as

DONALD H. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis________
Berkeley_____
Bennett______
Pieczynski____
Hallock______
Liddell______

NCBED-PE

17 October 1980

Defense Technical Information Center
ATTN: DTIS/DDA-2/Paul F. Cooper
Alexandria, VA 22314

Dear Mr. Cooper:

Enclosed are 12 copies of the report entitled, "Batavia Reservoir Compound Archaeological Summary," and appendicies. Please make the necessary arrangements to have this report and appendicies available from the National Technical Information Service, Springfield, VA.

If you require any further input, please feel free to contact me at the above address.

Sincerely,

1 Incl (12 cys)
as stated

THOMAS VAN WART
District Librarian

CF:
NCBED-PE

Lewis________
Berkeley_____
Bennett______
VanWart______

United States Department of the Interior
HERITAGE CONSERVATION AND RECREATION SERVICE
SOUTHEAST REGIONAL OFFICE
75 Spring Street S.W., Suite 1176
Atlanta, Georgia 30303

IN REPLY REFER TO:
W540

JUL 15 1980

Mr. Richard H. Lewis
Buffalo District, Corps
of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Mr. Lewis:

Due to staff reductions within the Office of Interagency Archeological Services-Atlanta, we are unable to review the report "Batavia Reservoir Compound, Phase I Archeological Survey." We will be happy to continue to receive reports for review from your office and will notify you on an as received basis which ones we will review. If you have any questions, please contact Mr. James Thomson at (404) 221-2633.

Sincerely,

Victor A. Carbone
Acting Chief

NCBED-PE 9 June 1980

Dr. Stephanie H. Rodeffer, Acting Chief
Interagency Archaeological Services - Atlanta
Heritage Conservation and Recreation Service
Richard B. Russel Federal Building
75 Spring Street
Atlanta, GA 30303

Dear Dr. Rodeffer:

Enclosed for your review and comment is a cultural resources reconnaissance report entitled "Batavia Reservoir Compound, Phase I Archaeological Summary" prepared for the Buffalo District by the State University of New York at Binghamton. This report is an update (which was required by project changes) of the cultural resourses report provided for your review in November 1979.

If we do not receive your comments within 30 days of your receipt of this letter, we will assume you are in agreement with the contents of the report. Comments received after the expiration of the comment period cannot be considered in the preparation of the final report.

If you have any questions regarding this matter, please contact my staff Archaeologist, Mr. Richard H. Lewis at (716) 876-5454, extension 2171.

Sincerely,

DONALD M. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis__________
Berkeley__________
Bennett__________
Pieczynski__________
Hallock__________
Liddell__________

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
700 East Water Street, Syracuse, New York 13210

June 23, 1976

Colonel Bernard C. Hughes
District Engineer
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Hughes:

We have reviewed the Draft Final Feasibility Main Report and Technical Appendix for the Interim Report on Feasibility of Flood Management in Tonawanda Creek Watershed, dated 1976, and have no comments to make on these submissions.

We appreciate the opportunity to review and comment on these reports.

Sincerely yours,

Henry Stewart for
Robert L. Hilliard
State Conservationist

FILE COPY
Checked by
Filed by

United States Department of the Interior

NATIONAL PARK SERVICE

NORTH ATLANTIC REGION

150 CAUSEWAY STREET

BOSTON, MA. 02114

IN REPLY REFER TO:

L-7619-NAR-(PE)

ER-76/456

June 22, 1976

Colonel Bernard C. Hughes
District Engineer
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Hughes:

This will serve as a multiple response to your request for review and comment of:

4 May on - Draft Environmental Statement, Proposed Flood Control, Tonawanda Creek Watershed, Erie, Genesee, Niagara, and Wyoming Counties, New York (originally sent to our Departmental Office of Environmental Project Review which advised our direct response to you).

24 May on - Draft Feasibility Report for Tonawanda Creek Watershed New York.

3 June on - Reconnaissance Level Literature Search and Records Review (cultural resources report-largely on archeological values) for Tonawanda Creek Watershed, New York. This report was prepared for the Corps by Barbour and Miller of Department of Anthropology, SUNY at Buffalo.

You should understand that our comments on the cultural resources report and the draft feasibility report are provided as technical assistance based solely on the interests, expertise and responsibilities of the National Park Service. The comments on the draft environmental statement are also those of the National Park Service as a portion of the collective expertise of the Department, but a consolidated Departmental commentary will be presented at a later date upon the Chief of Engineer's request to review the proposal.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

Cultural Resources Report. Because the findings of this report are basic to the development of an adequate environmental impact statement, we will speak to it first. The report appears adequate as a literature search and records review, and we note that many archeological and potential historical sites were identified. It is also noted that the State Historic Preservation Officer's office contributed a listing of sites on and recommended for listing on the National Register of Historic Places, as well as archeological sites on file with that office.

Draft Environmental Statement. Section 2, paragraphs 2.104 and 2.105 (pages 131-134) makes appropriate use of the information recorded in the cultural resources report. Appendix F-1, summary of that cultural resources report further emphasized the potential and probability of archeological resources in the overall study area. That summary reflects on the project alternative which would cause less effect on such resources and indicates that some alternatives would require much more detailed archeological investigations prior to final project design. Paragraph 2.104 indicates that consultation of the National Register of Historic Places has been accomplished. Up to this point, consideration for the protection of cultural resources would appear satisfactory. However, as this is where the consideration stops, we feel that necessary required considerations are incomplete.

We find this environmental statement deficient as now presented for failure to discuss accomplished or intended efforts to fulfill the requirements of EO 11593 and follow the procedures for compliance with Section 106 of the Historic Preservation Act as presented in 36 CFR Part 800. While it may be the intent to perform such compliance at a later project phase, the level of detail in discussing various alternatives in this draft environmental statement warrants a commensurate consideration for the protection of cultural resources so that the selection of the best alternative can be properly guided.

With the citation of all the National Register sites involved, certainly the alternative project selected is very likely to undergo Section 106 proceedings. Further, until the many archeological sites identified have been evaluated for their significance and eligibility for inclusion on the National Register of Historic Places, compliance with Section 106 requirements remains a potential threat to the accomplishment of the selected project alternative.

Section 4, paragraph 4.11.i (page 150) flatly states that "some cultural resources will be lost" with the mollification that preservation efforts will be considered in the public recreation development areas.

Paragraph 4.27 (page 154) expresses a partial approach to the protection of cultural resources. However, it would seem essential, even as an aspect of mitigation of harmful effects, to first determine where the cultural resources are that require protective measures.

We would remind you that the Director, Office of Archeology and Historic Preservation, National Park Service, Washington, D. C. 20240, will, upon request, provide a determination of eligibility of sites of historical or archeological significance for inclusion in the National Register of Historic Places.

Paragraph 9.04 (page 186) mentions initial coordination with the National Park Service as further identified in our technical assistance letter of January 5 displayed as Appendix B-1-2.

It is not our outlook that detailed archeological investigations should be performed over the entire study area. However, we are concerned that adequate considerations be given at this time for the protection of cultural resources commensurate with the detail of consideration given all other aspects leading to the selection of a project alternative. Certainly, the applicability and necessity for compliance with Section 106 should be discussed which beckons completion of EO 11593 requirements and applicable NEPA provisions already initiated. It would seem possible that the unfinished cultural resource protection consideration work can be satisfactorily completed before finalization of this environmental statement and that the present inadequacies in the treatment of this bona fide aspect of the human environment can be rectified in the final environmental statement.

Draft Feasibility Report. As indicated in our letter of January 5 included in Appendix F, we were pleased to note cultural resources coverage in the Preliminary Feasibility Report and fully expected to see an adequate treatment of cultural resource protection considerations in the following stages of the report. We are now concerned that all cultural resource considerations seem to have been dropped from the feasibility report, particularly when numerous other aspects and criteria, such as biological, climatological, land use, economical, recreational resources, along with population growth, transportation trends, housing needs and industrial activity factors are maintained and treated in significant detail in the main report and technical appendices. In a manner commensurate to the treatment of the many other factors mentioned above, we recommend that cultural resource protection considerations be included in the final report and that all efforts to comply with standing requirements for the protection of cultural resources should be clearly presented.

Again, in summary, it is not our intent to demand an excessive effort to survey, investigate and evaluate the impacts of every alternative.

Moreover, it is our purpose to technically assist the Corps in its responsibility to protect cultural resource values from adverse effects that may or will result from any selected project alternative.

Sincerely yours,

Gilbert W. Calhoun

Gilbert W. Calhoun
Acting Regional Director

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
NORTHEASTERN AREA, STATE AND PRIVATE FORESTRY
6816 MARKET STREET, UPPER DARBY, PA. 19082
215-596-1672

8400
June 18, 1976

LTC Byron G. Walker
Deputy District Engineer
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Refer to: NCBED-PE, Draft Environmental Statement
Tonawanda Creek Watershed
NY

Dear Col. Walker:

Of the four plans described in the above Statement, we consider the selected plan -- Batavia Reservoir -- the most environmentally sound. We understand that flood water inundation will not continue beyond a period that would cause damage to elm, ash, and cottonwood.

Loss of habitat and wetland appears unavoidable and to be the minimum compatible with completion of the project.

If possible, at dike and spillway construction areas (p. 153) seeding and mulching should be supplemented by planting trees and shrubs to restore wildlife habitat.

Sincerely,

Dale O. Vandenburg

DALE O. VANDENBURG
Staff Director
Environmental Quality
Evaluation

FILE COPY
Checked by

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Post Office and Courthouse Building
BOSTON MASSACHUSETTS 02109

JUL 12 1976

District Engineer
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Sir;

The following comments are provided in response to your May 24, 1976 letter to Mr. Willard W. Cole, Jr., field supervisor of the New York Area Office of the U.S. Fish and Wildlife Service, requesting comments on the Draft Final Feasibility Report for Tonawanda Creek Watershed, New York. Our comments are provided as field level review and are not the comments of the Department of the Interior as outlined under Section 2 (b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.)

The U.S. Fish and Wildlife Service reviewed the proposed project and provided a January 28, 1976 report to the District Engineer, Buffalo District on the Preliminary Feasibility report and a June 17, 1976 report reviewing your April 1976 draft environmental statement for Flood Control in the Tonawanda Creek Watershed, New York.

We appreciate the Corps of Engineers' selection of the Batavia Reservoir Compound amd believe that the project, as presented in your Draft Final Feasibility Report, will have the least environmentally damaging effects on fish and wildlife resources of the area. However, in Section VII E, outlining Data Needs, mention should be made of further need for environmental data. As discussed in our June 17, 1976 report, additional fish survey work, as well as more detailed field observations of vegetation and bird species within the vicinity of the Batavia Reservoir Compound are needed.

We appreciate the opportunity to review the Draft Feasibility Report at this time, and look forward to further coordination on the proposed project.

Sincerely yours,

ACTING Regional Director

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

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Filed by

United States Department of the Interior
NATIONAL PARK SERVICE
NORTH ATLANTIC REGION
150 CAUSEWAY STREET
BOSTON, MA. 02114

IN REPLY REFER TO:
L-7619-NAR-(CE)
NCBED-PN

January 5, 1976

Colonel Byron G. Walker
Deputy District Engineer
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Walker:

This responds to your letter of 15 December requesting our comments on the Preliminary Feasibility Report on Flood Management in the Tonawanda Creek Watershed, New York.

We are pleased to note the report's coverage of cultural resources (pp. 32 and 33) and the commitment to accomplish cultural resource literary studies. Further, we understand that the information found in these literary searches will be used in the identification and development of mitigating measures as necessary to protect cultural resources that may be affected by specific project works of the overall flood management plan.

We also note the report's mention of the Erie (later) Barge Canal in the study area. The further literary searches should help to focus on the recognized resources and probable archeological values related to that historic waterway. While we, at this time, see but one National Historic Landmark in the study area, there are doubtless a number of sites listed or in the process of being considered for inclusion on the National Register of Historic Places that could be affected by project work. Therefore, we would suggest that in addition to checking the National Register of Historic Places, contact should be maintained with the State Historic Preservation Officer (Mr. Orin Lehman, Commissioner, Parks and Recreation, Room 303, South Swan Street Building, Albany, New York 12223) to assure no oversight.

Literary research performed by competent archeologists should provide the necessary basis to determine the location and scope of field surveys and need for excavations to assure the utmost protection for any significant

AMERICAN REVOLUTION BICENTENNIAL

Filed by

archeological values that could be destroyed by project works. We would suggest contact with the New York Archeological Council (Dr. Thomas King, 4242 Ridge Lea Road, Buffalo, New York 14226) and/or the State Archeologist (Dr. Robert E. Funk, New York State Museum and Science Service, Albany, New York 12224) for assistance in pursuing the archeological sectors of the literary searches to be performed.

In addition to the above, concerning the protection of significant natural resources, we suggest that the literary search and other continuing investigations include a check of existing and potential National Natural Landmark designations. Assistance for identifying Natural Landmarks can be requested from this office or from our Natural Landmarks Specialist (Mr. Paul Favour, P. O. Box 187, Northeast Harbor, Maine 04662).

We will be most anxious to see and review the final feasibility study inclusive of natural and cultural resource protection considerations, and we appreciate this early opportunity to comment on this preliminary report.

Sincerely yours,

Jerry D. Wagers
Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
100 Grange Place, Room 202
Cortland, New York 13045

January 28, 1976

District Engineer
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Sir:

This responds to LTC Byron Walker's December 15, 1975 letter requesting our comments on your Preliminary Feasibility Report on Flood Management in the Tonawanda Creek Watershed, New York.

The following comments are provided as a result of informal field review. They are submitted by the U. S. Fish and Wildlife Service as technical assistance for input to your final plan for Flood Management in the Tonawanda Creek Watershed. Further review will be undertaken by this Service during the Departmental review process when the Departmental position will be provided.

The U. S. Fish and Wildlife Service has provided prior reports to the District Engineer, Buffalo District, on several of the flood management measures being considered in the Preliminary Feasibility Report. In our February 2,1960 report, we discussed the possible effects on fish and wildlife resources of modifications to the existing Corps project at Batavia and of a storage reservoir or reservoirs on the headwaters of Tonawanda Creek. On February 8, 1961, we issued a preliminary report on fish and wildlife resources of the Tonawanda Creek basin and then issued a supplemental to the preliminary report on October 2, 1967.

We have reviewed your Preliminary Feasibility Report and find that four regional measures and one local protection measure are presently being considered for Flood Management in the

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Tonawanda Creek Watershed. The four regional measures consist of Sierks Reservoir, Linden Reservoir, Alabama Pools, and the Batavia Reservoir Compound. The local protection measure involves the modification of the existing Corps project at Batavia, New York. These flood management measures have also been considered in combination to form several plans for basin flood management.

We offer the following specific comments on the considered flood management measures:

Batavia Reservoir Compound. This measure involves two shallow detention reservoirs arranged in series designed to intercept all runoff from that part of the Tonawanda Creek Watershed upstream from the city of Batavia, New York. Since these reservoirs will normally be dry, no significant fisheries impact can be expected except during the construction phase when some disturbance of the existing warmwater fishery, consisting of such species as smallmouth bass and northern pike, will occur.

Wildlife resources consist of a variety of species. There are white-tailed deer in the basin and upland game populations of pheasants and ruffed grouse. Muskrats, beavers, racoons, and red foxes as well as an occasional siting of otters are some of the furbearing mammals in the area. Waterfowl hunting occurs along Tonawanda Creek, its tributaries, and associated wetlands. The magnitude of this type of hunting in the proposed project area has not been determined. However, since the proposed reservoirs will normally be dry, no significant impact on wildife resources is currently expected.

One consideration that must be addressed,is the effect the Batavia Reservoir Compound will have on the present cooperative hunting area leased from local land owners by the New York State Department of Environmental Conservation (NYSDEC).

Modification to the Existing Batavia Project. This local protection measure involves levees, bank protection, and channel enlargement within the city of Batavia and downstream to Bushville, New York. The NYSDEC has no current fisheries data on this portion of the Tonawanda Creek. Expected warm-water species include smallmouth bass, northern pike, and some panfish and bullheads below Batavia. The channel modification's impacts on these fishery resources cannot be accurately determined at present due to the lack of current fishery data.

The Batavia to Bushville section of the Tonawanda Creek is primarily agricultural. Wildlife species that will be affected by the resultant disturbance of stream-bank vegetation from levees, bank protection, and channel enlargement consist of songbirds, some pheasant wintering area, and various furbearers including muskrats and possible otters.

Alabama Pools. This measure is a complex of reservoirs including both storage and detention reservoirs in the vicinity of the NYSDEC Tonawanda Wildlife Management Area (WMA). The Alabama Pools would have no beneficial effect on fisheries resources of the area, however, this alternative would have serious adverse consequences on wildlife resources associated with the state's existing Tonawanda WMA.

Coordination with the NYSDEC has indicated that the Tonawanda WMA habitat conditions are nearly ideal for the production, enhancement, and enjoyment of the waterfowl resource and other marsh-related wildlife species. The NYSDEC has presently spent upwards of $25,000 on establishing the ideal wetland habitat conditions which according to present data supports waterfowl hunting providing approximately 2500 man-days of recreation annually with an annual harvest of approximately 1500 ducks and geese. The Alabama Pools project would result in the destruction of much of the NYSDEC developmental work in the area. Recent expenditures by the NYSDEC have been made in order to prevent damaging flood waters from entering the Tonawanda WMA impoundments, just the opposite of the Alabama Pools proposal.

The present system of shallow marshlands created by the low dikes of the Tonawanda WMA supports aquatic submerged, emergent, and floating vegetation, together with small pockets of open water. These important wetland habitat conditions attract waterfowl for cover, resting. food, and nesting during the spring, summer, and fall. The storage of spring flood waters at the depths proposed in the Alabama Pools will result in disastrous effects on both aquatic and terrestrial vegetation. Desired growth of aquatic plants that do poorly in deep water, even for short periods of time,will be severely retarded or destroyed. Proposed spring flood water depths will also have serious adverse effects on nesting waterfowl and shorebirds as well as the valuable furbear resource present on the area.

The Alabama pools may also have severe adverse impacts on several rare and endangered bird species sighted around the Iroquois National Wildlife Refuge and Tonawanda Wildlife Management Area. These sightings include golden eagles (rare), bald eagles and the American Perigrine Falcon (endangered) and ospreys (undetermined). Additional studies on this matter are necessary.

Sierks Reservoir. This protection measure is a storage reservoir on Tonawanda Creek in the Cattaraugus Hills, near the hamlet of Sierks, New York. It is proposed as a multi-purpose project for flood management, fishery enhancement, recreation, water quality management and irrigation.

As discussed in our October 2, 1967 Fish and Wildlife Service Supplemental Report, fish and wildlife resources within the area of project influence involve a limited warm water fishery. This fishery is expected to consist of smallmouth bass, northern pike, rock bass, pumpkinseed, and bullhead.

Due to the limited warmwater fishery, Sierks Reservoir may afford substantial opportunitites for the development of this type of fishery as well as a possible trout fishery. However, the project area's wildlife resource will be lost through inundation. The project area supports a moderate wildlife population comprised of such species as cottontail rabbit, ruffed grouse, raccoon, and fox. Lack of suitable habitat is responsible for low populations of pheasants, muskrats, and waterfowl. The project area does, however, support a wintering area for white-tailed deer.

The multi-purpose benefits for this measure can only be determined after further detailed studies. The potential recreation and fishery benefits must be weighed against the loss of wildlife resources.

Linden Reservoir. This measure is a storage reservoir on Little Tonawanda Creek in the Cattaraugus Hills, near the hamlet of Linden, New York. It is proposed as a multi-purpose project for flood management, fishery enhancement, recreation, water quality management and irrigation.

This reservoir would probably permit the development of a warm-water fishery superior to the existing stream fishery. Little Tonawanda Creek within the project area is fairly sluggish with erodible, silty banks, and little cover. Although the stream is less than ideal, it is being stocked with brown trout by the NYSDEC in a 3.2 mile stretch extending upstream from just above Linden to Dale, New York. Fishery resources within the project area also include panfish (primarily rockbass), suckers, and common shiners and associated minnows.

AD-A101 439 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2
BUFFALO METROPOLITAN AREA, NEW YORK WATER RESOURCES MANAGEMENT --ETC(U)
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The proposed project area supports a moderate population of wildlife including white-tailed deer, cottontail rabbit, ruffed grouse, raccoon, and fox. As found at the proposed Sierks Reservoir area, lack of suitable habitat is responsible for low populations of pheasant, waterfowl and muskrat.

The construction of Linden Reservoir will result in the loss of wildlife resources as well as the present NYSDEC brown trout stream stocking program. These losses must be considered when discussing the potential benefits of recreation and an improved warmwater fishery. The multi-purpose benefits for this measure can only be determined after further detailed studies.

Of the four regional and one local protection measures presented in your Preliminary Feasibility Report, the Batavia Reservoir Compound will have the least impact on fish and wildlife resources. This measure will also benefit the NYSDEC Tonawanda Wildlife Management Area by preventing inundation from floodwaters. The Alabama Pools measure will have the most disastrous impact on fish and wildlife resources. This measure will destroy the already present ideal habitat conditions for production, enhancement, and enjoyment of the waterfowl resource and other marsh-related wildlife species.

We appreciate the opportunity to comment on your Preliminary Feasibility Report at this time and look forward to further coordination on the Tonawanda Creek Watershed Flood Management project.

Sincerely yours,

Willard W. Cole, Jr.

Willard W. Cole, Jr.
Area Office Supervisor

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1980

INPUT FROM STATE AGENCIES

U. S. Army Corps of Engineers
Buffalo District
Buffalo, New York

NCBED-PE 17 October 1980

Dr. Robert Funk
State Archaeologist
University of the State
of New York
State Education Department
Cultural Education Center
Albany, NY 12230

Dear Dr. Funk:

Enclosed for your information is a Final Cultural Resources Report entitled, Batavia Reservoir Compound: Phase I Archaeological Summary and Appendicies.

If you have any questions regarding this report, please contact Mr. Richard H. Lewis, Staff Archaeologist, at (716) 876-5454, extension 2175.

Sincerely,

3 Incl
as stated

DONALD M. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis______
Berkeley____
Bennett_____
Pieczynski__
Hallock_____
Liddell_____

NCBED-PE 17 October 1980

Ms. Ann Webster Smith
Deputy Commissioner for
Historic Preservation
New York State Office of
Parks and Recreation
Agency Building #1
Empire State Plaza
Albany, NY 12238

Dear Ms. Smith:

Enclosed for your information is a Final Cultural Resources Report entitled, Batavia Reservoir Compound: Phase I Archaeological Summary and Appendicies.

If you have any questions regarding this report, please contact Mr. Richard H. Lewis, Staff Archaeologist, at (716) 876-5454, extension 2175.

Sincerely,

3 Incl
as stated

DONALD M. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis____
Berkeley____
Bennett____
Pieczynski____
Hallock____
Liddell____

NEW YORK STATE PARKS & RECREATION Agency Building 1, Empire State Plaza, Albany, New York 12238 Information 518 474-0456
Orin Lehman, Commissioner

June 27, 1980

Mr. Donald Liddell
Chief, Engineering Division
Dept. of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, N.Y. 14207

Dear Mr. Liddell:

Batavia Reservoir Compound
Genesee County, New York

We have reviewed the cultural resource reconnaissance report on this project and wish to make a few comments. The survey seems to be complete and the recommendations are in order. However, the structure survey forms do not provide sufficient information for us to evaluate them. The contact prints are not adequate particularly in cases where the structure may well be eligible for the National Register. Photos should be attached to the form as indicated on the form and in the enclosed manual. Also, an overall map should be included with forms keyed to it. This can be a USGS map if scale is a problem. We suggest you have your consultants follow the instructions in the manual for architectural and historical information as well.

Due to the large number of structures included in this study, it may be beneficial to wait until you know which structures are to be affected before a detail study is made.

Please call Bruce Fullem at 518-474-3176 should you wish to discuss this matter in detail.

Sincerely,

Stephen J. Raiche
Director
Historic Preservation Field
Services

ENG COPY
Checked By
Filed by

BF:mr

Enc.

NCBED-PE 9 June 1980

Dr. Robert Funk, State Archaeologist
New York State Museum and Science Service
Anthropological Survey
Albany, NY 12234

Dear Dr. Funk:

Enclosed for your review and comment is a cultural resources reconnaissance report entitled "Batavia Reservoir Compound, Phase I Archaeological Summary" prepared for the Buffalo District by the State University of New York at Binghamton. This report is an update (which was required by project changes) of the cultural resourses report provided for your review in November 1979.

If we do not receive your comments within 30 days of your receipt of this letter, we will assume you are in agreement with the contents of the report. Comments received after the expiration of the comment period cannot be considered in the preparation of the final report.

If you have any questions regarding this matter, please contact my staff Archaeologist, Mr. Richard H. Lewis at (716) 876-5454, extension 2171.

Sincerely,

DONALD M. LIDDELL
Chief, Engineering Division

CF:
√NCBED-PE

Lewis__________
Berkeley__________
Bennett__________
Pieczynski__________
Hallock__________
Liddell__________

NCBED-PE

9 June 1980

Dr. Ann Webster-Smith, Deputy Commissioner
for Historic Preservation
Division for Historic Preservation
New York State Office of Parks and
Recreation
Agency Building No. 1
Empire State Plaza
Ablany, NY 12238

Dear Dr. Webster-Smith:

Enclosed for your review and comment is a cultural resources reconnaissance report entitled "Batavia Reservoir Compound, Phase I Archaeological Summary" prepared for the Buffalo District by the State University of New York at Binghamton. This report is an update (which was required by project changes) of the cultural resourses report provided for your review in November 1979.

If we do not receive your comments within 30 days of your receipt of this letter, we will assume you are in agreement with the contents of the report. Comments received after the expiration of the comment period cannot be considered in the preparation of the final report.

If you have any questions regarding this matter, please contact my staff Archaeologist, Mr. Richard H. Lewis at (716) 876-5454, extension 2171.

Sincerely,

DONALD M. LIDDELL
Chief, Engineering Division

CF:
NCBED-PE

Lewis__________
Berkeley________
Bennett_________
Pieczynski______
Hallock_________
Liddell_________

Genesee County
Soil and Water Conservation District

5272 Clinton Street Road · Batavia, New York 14020 · Phone (716) 343-2362

October 29, 1979

Mr. Ronald J. Guido
Chief, Economics Section
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Ron:

After reviewing the material sent regarding the BRMC in Genesee County, we offer the following comments:

1) The study appears to be well written and based on the materials and data used, a significant benefit should be achieved.

2) There is no doubt that some time will elapse before the full "improvement" impact will be seen, but gradually landowners in the area should begin to utilize the abandoned or idle land. However, intensification could occur from more than one direction.

   If annual flooding in the lower region is controlled during the growing season, dairy men in the area might utilize more of the idle land for livestock crop production such as oats, corn and hay.

   Also cash crop farmers not necessarily in the area, may also begin to renovate the idle land for more intensive crops such as cabbage, dry beans, beets, sunflowers, etc.

   A third prospect would be a combination of the two, whereas a dairy man might diversify by adding some acreage of cash crops as he presently produces enough feed and still has extra land now capable of growing and harvesting crops.

3) Much of the idle land will need improved internal water management in order to compete in crop production. This is an assumption based on the premis that the land was abandoned due to prolonged wetness after the initial flooding had subsided.

   Internal water management can be obtained through the use of land leveling and filling, open drainage channels, subsurface tile installation and diversion of over land flow from adjacent higher land.

Genesee County
Soil and Water Conservation District

5272 Clinton Street Road · Batavia, New York 14020 · Phone (716) 343-2362

Ronald J. Guido
Page 2

4) Channel improvement particularly in the area between the upper and lower impoundments, would add an extra dimension to water control in the area. Often high flows (not bankfull) back up at the log jams and flow into adjacent fields causing local flooding and crop loss. The removal of impediments with in the channel proper, would reduce the severity of annual summer crop losses along certain sections of the stream.

5) In referance to item G on the included disposition form dated Sept. 26, 1979 from R. Waxmonsky to you, we completely agree with this and think it will be one of the points of contention.

   However, I also think a similar problem may occur in the lower area with the farms where buildings and facilities will require removal.

In closing, please feel free to call for any additional information you may need. Either Art Hanson or myself are available at 716-343-2362.

Respectfully,

Bob

Robert Berkemeier
District Manager

RB/jg

ls/2177

NCBED-PC

5 October 1979

Mr. Robert Berkmeier
Genesee County Soil & Water
Conservation District
5272 Clinton Street Road
Batavia, NY 14020

Dear Mr. Berkmeier:

As agreed in our meeting of 24 September 1979, I am forwarding you some material relating to the agricultural component of the Tonawanda Creek study we are presently concluding. This includes a draft copy of the agricultural section of the Economic Supplement to the Revised Interim Feasibility Report and a copy of an in-house memo from R. Waxmonsky to me dated 26 Sep 79. The latter specifically relates to the impact alternative plans would have upon agriculture in the two reservoir sites.

I would appreciate your reviewing these materials in light of your knowledge and experience with agriculture on the Tonawanda Creek flood plain. I would like to receive your written comments by Monday, 29 October, so that we might consider them before we hold a public information and status meeting on the project in the city of Batavia on 8 November 1979.

Should you have any questions, please feel free to phone me, Area Code (716) 876-5454, extension 2177.

Sincerely,

2 Incl
as stated

RONALD J. GUIDO
Chief, Economics Section

CF:
NCBED-PC
NCBED-PN/J. Hassey

Waxmonsky____
Guido________

NCBED-PC
R. Guido

The Effect of Alternative Reservoir Managment Plans Upon Agriculture in Reaches T-13 L and T-13 U
R. Waxmonsky
26 Sep 79
Waxmonsky/ls/2178

After having talked with Brad and Mike this morning, I would restate my 7 Aug 79 memo as follows:

a. Given the historical record of flowage in Tonawanda Creek at the Batavia Gage for the 1945-1970 period, it is estimated that only three floods in the 16 April to 1 July period would have overspilled the bank in T-13 Lower (the area between the two reservoirs) under existing (that is, with natural or without project) conditions.

b. If the Batavia Reservoir Compound-Modified had been in place in 1945, only one of these floods would have impounded water in T-13 Lower. This would have been the 25 April 1961 flood. This assumes "winter operation" of the two reservoirs - the floodgates in each reservoir are partially closed.

c. Under with project and winter operation conditions, an area of 1,250 acres would be inundated in Reach T-13 Lower by this flood. This compares to 870 acres which are estimated to have been inundated under existing (natural) conditions in April 1961. The depth of the pooled water would have been 5.3 feet greater under with project and winter operation conditions than under existing (natural) conditions. Under the improved and winter operation conditions, an area of 350 acres would be inundated in the Upper Reservoir (T-13 Upper); this compares to 45 acres which was estimated to have been unundated under existing (natural) conditions in April 1961. The depth of pooled water in the Upper Reservoir would have been 9.4 feet greater under with project and winter conditions than under existing (natural) conditions in 1961.

d. The 25 April 1961 flood would have been out-of-bank for seven days in T-13 Lower under with project and winter operation conditions; this is four days longer than it has been estimated; it was out-of-bank under existing (natural) conditions in April 1961. The additional four days would not have had a significant affect on spring planting as field preparation could have begun by 15 May; at a minimum, it would not have significantly hindered the planting of corn. The same flood would have been out-of-bank in T-13 Upper for approximately four days under the same conditions. Since it has been estimated that there was no flooding in T-13 Upper under existing (natural) conditions, this is a net and an absolute increase in the duration of flooding in the area. However, for the reason given in the discussion of T-13 Upper above, the flooding would not significantly hinder the planting of corn. It could, however, significantly delay the planting of oats in T-13 Upper. But, as no oats were planted in T-13 Upper in 1978, this may well be insignificant.

e. Since the project would have eliminated all but one flood during the 16 April to 1 July period in the 25 years from 1945 to 1970, there is a four percent risk in any one year of a flood occurring in T-13 Upper during the 16 April to 1 July period. Consequently, at a maximum, there is a four percent risk of agricultural crop damage in the reach from a flood occurring during this period of time. Though the value of the damage could amount to as much as the total agricultural revenue produced in the

reach minus all remaining unexpended variable production costs, the probability that the damage would be this great is relativly small. Most probably, damages associated with a flood in the 16 April to 1 July period would be substantially below the above mentioned maximum value.

f. Operation of the project on a "summer operation" plan (closing the floodgates of the upper reservoir to as great an extent as possibly and as frequently as possible) would reduce the flowage into the lower reservoir site, T-13 Lower. This would greatly reduce the probability of the very slight but very frequent floods (annual floods) which currently inundate low lying areas along the creek. This would increase the productivity of these lands and would produce some agricultural benefits which would tend to offset the increase loss farmers in T-13 Lower would experience from more frequent impounding of water on their land under the project and winter operation conditions. This would further reduce the magnitude of the latter loss.

g. Though "summer operation" of the two reservoirs would increase the utility and productivity of lands in the lower reservoir (T-13 Lower) by reducing the frequency and extent of the slight but frequent (annual) floods, it would do so at the expense of farm operations in the upper reservoir site (T-13 Upper). Here, the effect would be to increase agricultural losses because the area would be flooded more frequently, and a greater area would be flooded to a greater depth, under summer operation than under winter operation or under existing (natural conditions. This increased loss to upper reservoir farmers would be compensated by paying them a relatively high flowage easement price which would presumably compensate them for their increase loss. Since they will still own the land, they will still be able to use it as they choose, and as conditions permit in nonflood periods.

RAYMOND WAXMONSKY
Regional Economist

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
Raymond T. Schuler, Commissioner

1220 Washington Avenue, State Campus, Albany, New York 12226

December 8, 1975

LTC Byron G. Walker
Corps of Engineers
Deputy District Engineer
Department of the Army
1776 Niagara Street
Buffalo, New York 14207

Dear LTC Walker:

Your letter of December 1 has been received and forwarded to Mr. K. W. Shiatte, Director of our Development Division, for reply. Any future correspondence should be directed to Mr. Shiatte at the following address:

Mr. K. W. Shiatte, Director
Development Division
New York State Department of Transportation
1220 Washington Avenue
State Campus
Albany, New York 12232

Please send a carbon copy of the notification letter, without attachments, to Mr. J. K. Mladinov, Assistant Commissioner for Planning and Development, at the above address. Thank you.

Sincerely yours,

Wilson Campbell

E. Wilson Campbell
Director, Planning Division

EWC:BHC

FILE COPY
Checked by
Filed by

New York State Department of Environmental Conservation
Region 9 Fish & Wildlife Office
128 South Street
Olean, New York 14760

Ogden Reid,
Commissioner

December 18, 1975

Mr. Bernard C. Hughes
Colonel, Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Hughes,

I did not have an opportunity to attend the public meeting November 20, 1975 concerning flood management along the Tonawanda Creek.

I would like to bring your attention to a matter of interest to the Region 9 Wildlife Unit concerning the study area.

Region 9 Wildlife personnel have identified a major deer wintering area in the Tonawanda Creek valley between the Sierks reservoir dam site and Varysburg in Wyoming County. It is entirely possible that a reservoir in this area would significantly affect this wintering area and consequently the deer herd in a much larger area. I have encircled in red on a map of the study area the approximate location of the area of concern. A detailed analysis of the effects of a reservoir in this area will require considerable time.

Thank you for the opportunity to comment on this proposal.

Very truly yours,

R L Cheney

Russell L. Cheney
Regional Wildlife Manager
Region 9

RLC/dm
Encl.
cc: L.S. Nelson
J. Dell

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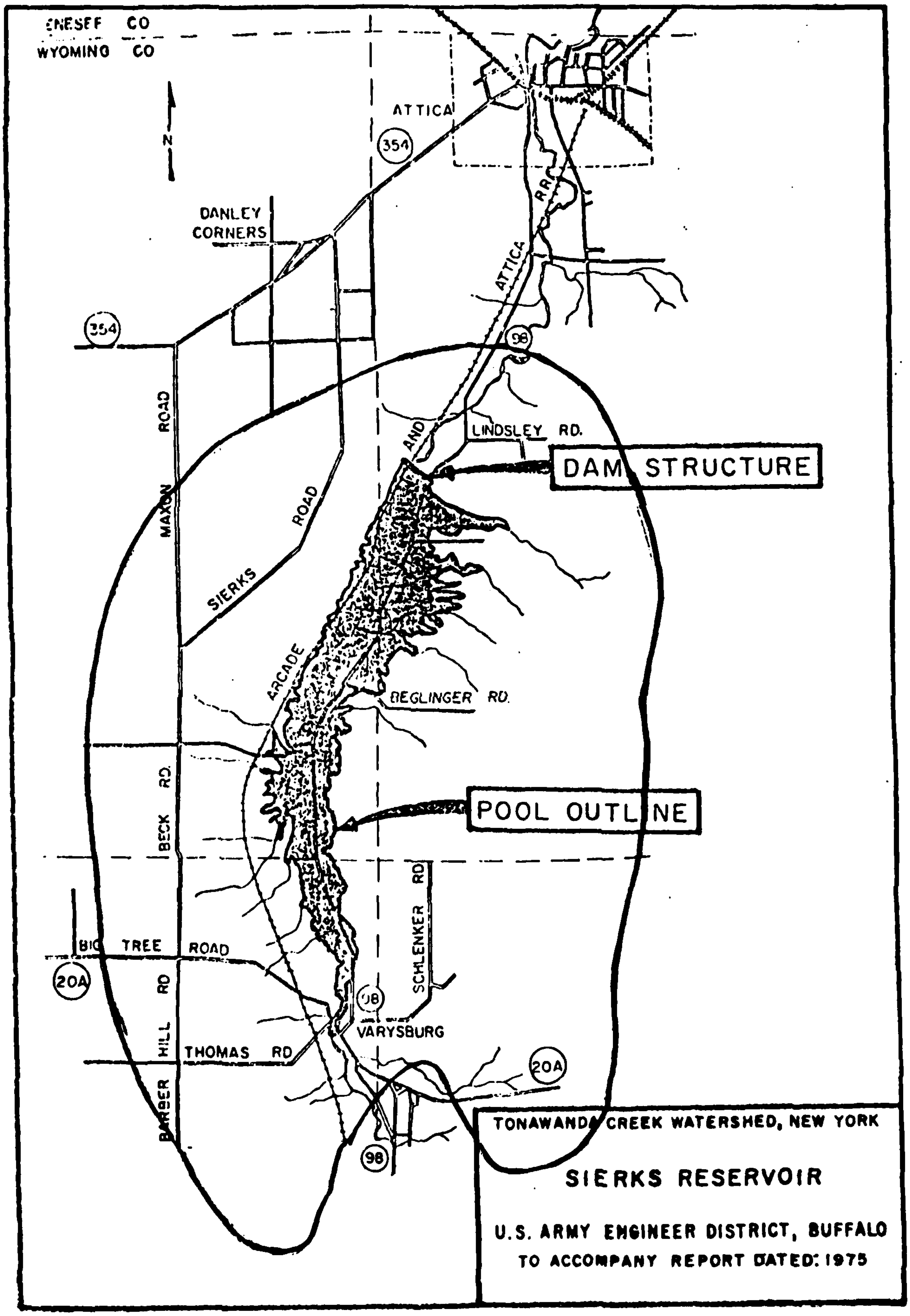
Filed by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TONAWANDA CREEK WATERSHED, NEW YORK
SIERKS RESERVOIR
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: 1975

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Ogden Reid,
Commissioner

January 7, 1976

Colonel Bernard C. Hughes
District Engineer
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Hughes:

We have reviewed your report entitled Considered Structural Alternatives for Flood Control in the Tonawanda Creek, New York and have the following comments:

1. Alternative #1 - Sierks Reservoir

   Although this alternative would be consistent with the State-adopted Erie-Niagara Basin Plan, there are several significant environmental concerns which must be considered. A major deer wintering area in the Tonawanda Creek Valley between the Sierks reservoir dam site and Varysburg has been identified. It appears that a reservoir in this area would significantly affect this wintering area and consequently, the deer herd in a much larger area. In addition, the impacts associated with relocating Route 98, which is presently within the proposed reservoir pool, will have to be carefully evaluated. The impact of the project on wetlands and active agricultural activities must also be considered.

2. Alternative #2 - Linden Reservoir

   This measure is also consistent with the State-adopted Erie-Niagara Basin Plan. Although no specific adverse impacts have been identied, the impact of the project on wetlands and active agricultural activities will have to be carefully reviewed as additional information becomes available.

3. Alternative #3 - Alabama Pools

   One of our major concerns is the potential loss of wetlands resulting from various alternatives of the watershed project. The Alabama Pools alternative appears to have the greatest potential for adverse impacts on wetlands. It may have an adverse impact on the Tonawanda Wildlife Management Area, which has been developed approximately 80% by this Department, and would negate some of the previously completed development. In addition, this measure may affect portions of two agricultural districts comprising approximately 43,000 acres in the Towns of Batavia, Alabama, Oakfield and Pembroke.

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Checked by
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4. <u>Alternative #4 - Batavia Reservoir Compound</u>

From an environmental viewpoint, this measure would probably have the least amount of adverse impacts when compared to the other alternatives. A major concern in conjunction with this measure would be the loss of productive farmland. However, since both detention reservoirs would normally be dry, provisions could be made to permit existing farming operations to continue as long as such activities do not affect the integrity of the flood protection provided. In addition, the limited period of flood water inundation associated with these types of structures (dry dams) would probably have a minimal impact on wetlands and wildlife habitat within the project area.

5. <u>Alternative #5 - Modification to Existing Corps Project at Batavia</u>

This measure may have a significant impact on Tonawanda Creek in the Batavia area, which could conflict with fishery management plans. The potential for adverse impacts would result primarily from the recommended enlargement of the stream channel for approximately 2½ miles.

Thank you for the opportunity to review the proposed project alternatives. We, of course, would like to receive additional information as it becomes available.

Very truly yours,

Terence P. Curran
Director of Environmental Analysis

BUFFALO METROPOLITAN AREA, NEW YORK
WATER RESOURCES MANAGEMENT STUDY

TONAWANDA CREEK WATERSHED
INTERIM FLOOD MANAGEMENT STUDY

FINAL FEASIBILITY REPORT

1980

INPUT FROM LOCAL INTERESTS

U. S. Army Corps of Engineers
Buffalo District
Buffalo, New York

GENESEE COUNTY LEGISLATURE

GENESEE COUNTY BUILDING
Administrative Office

OFFICE OF THE CHAIRMAN
James E. Woodruff

Phone (716) 344-2550

BATAVIA, NEW YORK 14020

November 21, 1979

Colonel George P. Johnson
District Engineer
U. S. ARMY CORPS OF ENGINEERS
Buffalo District
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Johnson:

The Buffalo District Army Corps of Engineers held a meeting on November 8, 1979, in Batavia, New York at the Genesee County Building No. 2, for the express purpose of explaining their plan known as "The Batavia Reservoir Compound Modified." This plan appears to meet the approval of persons from the City of Batavia who had concerns about the location of the dam in the earlier proposal.

Approximately one-hundred people attended the meeting at County Building No. 2, of which a few had any objections. It appeared that the majority are in agreement with the proposal.

The meeting was conducted very well by CORPS personnel and most questions were answered.

I would also like to take this opportunity to thank you and your organization for your sincere endeavors to assist the County of Genesee on this project.

Very truly yours,

James E. Woodruff

JAMES E. WOODRUFF
CHAIRMAN, GENESEE COUNTY LEGISLATURE

JEW/apc

ERIE & NIAGARA COUNTIES REGIONAL PLANNING BOARD

[illegible]
DIRECTOR

Gerald F. Hall
CHAIRMAN

James [illegible] Ryan
VICE CHAIRMAN

Joseph [illegible] Williams
SECRETARY

November 20, 1979

Mr. Joseph Hasey
Department of the Army
U.S. Army Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, New York 14207

RE: Tonawanda Creek Watershed Study

Dear Mr. Hasey:

This office has reviewed the proposed Batavia Reservoir Compound Plan of the referenced study and has noted that some limited benefits will result to the Erie and Niagara Region. The Regional Board therefore supports the proposed plan, however, wishes to emphasize that a regional solution to the entire Tonawanda Creek Watershed is required in order to alleviate present and future flood damages. It must also be pointed out that the downstream reaches include the fastest growing areas in the watershed (Town of Amherst and Clarence) and that the present benefit to cost ratio may not be a true barometer of future needs.

The Regional Board therefore respectfully requests that other alternate plans such as diversion channels, channelization and smaller reservoir compound plans be addressed for the Erie and Niagara Region and supplement the Batavia Reservoir thus insuring a regional solution.

Very truly yours,

Henry C. Jawor

Henry C. Jawor, P.E.
Sanitary Engineer

HCJ:sw

NORTHTOWN PLAZA 3103 SHERIDAN DR. AMHERST NEW YORK 14226 • PHONE ERIE COUNTY (716) 837-2035 NIAGARA COUNTY (716) 625-8114

November 20, 1979

Mr. Joseph Hassey
Project Engineer
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Sir:

As Chairman of the Tonawanda Creek Watershed Committee, I would like this letter to become a part of the record in regard to the planned "Batavia Reservoir Compound Modified" flood control project.

In attending the November 8th meeting in Batavia, which was conducted by the Corps of Engineers, it would seem quite evident that the vast majority were satisfied or in favor of the plans to control flooding along the Tonawanda Creek. I further believe that most people will agree on the need for flood protection today or the need will surely grow greater in the years ahead.

Very truly yours,

Frank Gorecki

FRANK GORECKI
CHAIRMAN
TONAWANDA CREEK WATERSHED COMMITTEE

FG/apc

TOWN OF BATAVIA
TOWN HALL
4165 WEST MAIN STREET ROAD
BATAVIA, NEW YORK 14020

FOUNDED 1802

January 10, 1976

Mr. Byron G. Walker
LTC. Corps of Engineers
Deputy District Engineer
Department of the Army
Buffalo District
1776 Niagara Street
Buffalo, New York 14207

Dear Mr. Walker:

We enclose herewith our master plan, existing zoning ordinance together with amendments for your information and reference in accordance to your letter sent to me on December 10, 1975.

Sincerely yours,

John T. O'Brien

John ~~T.~~ O'Brien, Chairman
Town of Batavia Planning Board

JTO:v
encs.

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Checked by
Filed by

DEPARTMENT OF PLANNING

PLANNING BOARD

3837 WEST MAIN STREET ROAD
BATAVIA, NEW YORK
PHONE (716) 343 1187

Gail Seamans CHM.
Dominic Mancuso V. CHM.
Dwight Wells DIR.

December 16, 1975

Mr. Byron G. Walker
LTC, Corps of Engineers
Deputy District Engineer
1776 Niagara Street
Buffalo, New York 14207

Dear Mr. Walker:

Thank you for the information on the flood management control proposal for the Tonawanda Creek Watershed.

Alternatives 1 and 2 do not directly affect land in Genesee County. However, alternative 2 is important to our county because of its creation of a source of water which could be used in developing a countywide water supply system. We also feel that alternative 2 would provide necessary control of the level of the Tonawanda Creek as it flows north so as to reduce the spring flooding in lands in the Towns of Bethany and Alexander.

Alternative 3, which is on the Tonawanda Game Management Area, does not conflict in any way with land use planning as seen by the county planning department. We favor further development and resource conservation measures in the Tonawanda Game Management Area so as to maximize the opportunity for wildlife management and public utilization of that area for conservation/education activities.

Alternative 4, entitled the Batavia Reservoir Compound, does affect a rather substantial amount of land in the Town of Bethany. Present land use plans call for continuation of this land as agricultural. As examination would show that the creation of these compounds would reduce the annual flooding of the more extensive lands in the Towns of Bethany and Alexander, the county planning board would be supportive of such an approach. We also feel that the creation o these compounds could create a recreational area usable by people from all over Western New York. We feel that from a cost benefit analyses that alternative 4

should be given priority from the corps.

The proposal outline in alternative 5 would seem to fit nicely with alternative 4 for an overall program of flood control and recreational development for the area along the Tonawanda in the City and Town of Batavia.

We would appreciate receiving any further information as it becomes available and would be more than happy to work with the corps as it nears implementation of one or more of the alternatives.

Sincerely yours,

Dwight H. Wells

Dwight M. Wells, Director
Genesee County Dept. of Planning

DMW:vmm

County of Erie

EDWARD V. REGAN
COUNTY EXECUTIVE

DIVISION OF PLANNING

CHARLES O. BROWN
DIRECTOR

PHONE: 716 - 846-831

December 17, 1975

Bryon G. Walker, Deputy District Engineer
Department of the Army
Buffalo District Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Ltc. Walker:

This is written in reference to your letter of December 1, 1975 regarding a draft environmental impact statement on a preliminary feasibility report entitled "Buffalo Metropolitan Area, New York, Water Resources Management Interim Report on Feasibility of Flood Management in the Tonawanda Creek Watershed."

You have requested basic information in knowing whether or not the various project alternatives will conform or conflict with the various land use plans, policies, controls, etc. of the indicated area.

In our evaluation of the various town master plans and zoning regulations of the effected towns in Erie County, the project should have no significant control on Erie County. None of the recommended alternates appear to have any detrimental effects upon land use development in this area, and the reduction of possible flood damage and the improvement of water quality will be beneficial.

Sincerely,

CHARLES O. BROWN
Director

sm

RIE & NIAGARA COUNTIES REGIONAL PLANNING BOAR

Leo J. Nowak, Jr.
DIRECTOR

Donald P. Lu
CHAIRMAN

Susan R. Gre
VICE-CHAIRMAN

H. William Dc
SECRETARY

December 18, 1975

Byron G. Walker
LTC, Corps of Engineers
Deputy District Engineer
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Walker:

Thank you for your letter of December1, 1975 requesting our comments and input to the Environmental Impact Statement on Flood Management in the Tonawanda Creek Watershed.

We are enclosing herewith a copy of the statement submitted by the Utilities Committee of the Regional Planning Board and given at the November 20, 1975 public meeting in Batavia, New York.

On November 18, 1975 Colonel Hughes wrote a letter regarding our presentation of the Tonawanda Creek Watershed Storm Drainage Proposals as recommended in our "Storm Drainage Management Plan", a copy of which the Buffalo District has in its files.

The Utilities Committee is meeting on December 18 at 10:00 a.m. in the Grand Island Town Hall. The committee will be reviewing this letter and has asked Colonel Hughes to attend their meeting to further discuss the differences between the Corps proposals and the RPB proposals and the problems caused through separate presentations. The Utilities Committee holds open meetings and anyone is free to attend. Should you desire to attend along with Colonel Hughes, please feel free to do so.

Very truly yours,

Leo Nowak Jr.

Leo J. Nowak, Jr., Director

LJN:meg
Encs.

Statement from the Utilities Committee of the Erie and Niagara Counties Regional Planning Board Regard the U. S. Army Corps of Engineers Alternative Plans for Flood Control on Tonawanda Creek to be given at the Public Meeting in Batavia on November 20, 1975

My name is Robert Floyd and I am here representing the Utilities Committee of the Erie and Niagara Counties Regional Planning Board.

The Board has completed a Storm Drainage Study covering the major watersheds of Erie and Niagara Counties. This study was funded by a grant from the U. S. Dept. of Housing and Urban Development. The region was divided up into 15 major watersheds, one of which is the Tonawanda Creek Watershed which the Corps of Engineers has presented here tonight. We are presently in the process of showing alternative solutions to the flooding problems as determined by the study and requesting public comments thereon.

On completion of the public presentations, the RPB expects to adopt a storm drainage plan and program consisting of a map and a report covering both Erie and Niagara Counties.

The plan and program now being presented by ENCRPB for Tonawanda Creek consists of a recommended plan and 4 alternatives, which identifies areas in need of flood protection in Erie and Niagara Counties along Tonawanda Creek.

The recommended plan calls for a two phase program the 1st phase being the construction of a floodway or diversion channel from the Barge Canal east to Transit Road with levees along Transit Road to divert the Black Creek flow to the diversion channel. Second stage construction will extend the diversion channel from Transit Road east to Tonawanda Creek with another levee in the

construction of the Alabama Pools should the need ever arise. Land use controls are also included in this solution.

Alternative No. 1 consists of individual protection such as construction allowed only above the 100 year flood level and then through the use of detention ponds by the developers to prevent further damages downstream due to the increased runoff generated.

Alternate No. 2

Excavation of Existing Channel: Tonawanda Creek would be deepened upstream from Mud Creek (mile 13.0 to 13.6) and near Rapids (mile 17.6 to 19.4). Low levees would be constructed across the Tonawanda-Black Creek Divide near Beeman Creek.

Alternate No. 3

Excavation of Existing Channel Combined with Alabama Pools: Alternative 2 would be combined with two inches of flood control storage over the upper Tonawanda Creek Watershed in the proposed Alabama Pools. The proposed Alabama Pools are located on the Erie-Genesee County line off-channel north from Tonawanda Creek. Low levees would be constructed across the Tonawanda-Black Creek divide.

Alternate No. 4

Complete Flood Plain Zoning: The entire broad flat flood plain would be used for non-flood vulnerable use.

In reviewing the U. S. Army Corps of Engineers alternative projects, we note the following:

2. The Alabama Pools solution but with modifications to the present Batavia Flood Control Project and without the levee and channelization projects in the Towns of Clarence and Newstead in Erie County.

3. The addition of Sierks and Linden Reservoirs a possible solution but with less protection especially in the downstream reaches.

4. The Alabama Pool solution but with Sierks Reservoir in lieu of the downstream levees and channelizations.

5. The no action and no structural action alternatives have been ruled out because they fail to meet the flood protection needs of the watershed.

The Utilities Committee of the RPB would like to go on record here tonight that the Corps of Engineers include in the next step of the study process th following:

1. Inclusion of the two phase Black Creek Diversion Channel Alternative as recommended in the RPB's Storm Drainage Management Study. This Study shows $276,000 annual cost versus $365,000 for the proposed study presented here tonight.

2. Inclusion of the no action alternative as required by the NEPA act.

3. The Alabama Pools alternate with the use of levees and channelization as shown in the RPB's Storm Drainage Study as an alternative to its recommended plan.

4. That the corps define the 100 year flood prone area and indicate through mapping the areas which will be no longer flooded for each o alternatives studied.

The Committee is concerned that certain areas are developed and are developing in Erie and Niagara Counties and in order to place sufficient information in the hands of the residents affected that all alternatives possible and their impact be clearly defined so that adequate public opinion can be secured and a final solution justified to the satisfaction of the public.

The Utilities Committee thanks the Corps for the opportunity to present this statement and also expresses a continuing interest in the project and desires to participate to its fullest extent. Thank you Col. Hughes.

ORLEANS COUNTY PLANNING BOARD

Court House Square
Albion, New York 14411

Mr. Byron G. Walker
LTC, Corps of Engineers
Deputy District Engineer
Buffalo District
1776 Niagara St.
Buffalo, N.Y. 14207

Dear Mr. Walker:

This is in response to your December 1 letter to Mr. Pahura regarding the Tonowanda Creek Watershed Management Feasibility interim report.

We appreciate your willingness to let us respond although this proposed flood mangement program has a relatively minor impact on Orleans County.

The only proposed area of impact involves lands in the extreme southwest corner of our county where Niagara and Genesee Counties abut Orleans.

Most of the land in question is part of the Oak Orchard Swamp and is under federal management. The County Planning Board's Preliminary Land Use Plan calls for continued protection of these lands as a natural wildlife refuge. Other areas, adjacent to Oak Orchard Swamp are designated as resource management areas.

The Shelby Township zoning ordinance designates other adjacent areas as agricultural use districts. However, the residential use district is defined in the ordinance as follows: "...For the purpose of this Ordinance those lands in the Agricultural Use Districts which are adjacent, opposite or within three hundred (300) feet, measured along the road frontages on both sides of the road, to a premise on which a one or two family dwelling, other than a farm dwelling, has been or may in the future be established shall be a Residential Use District and shall be subject to the provisions of this Ordinance applicable to the Residential Use Districts."

In effect this ordinance allows for and encourages the strip development of all roadways in the Town of Shelby. The County Planning Board opposes strip development of any nature. However, it is a fact of which you should be cognizant as it appears there are local roadways which are located in that area of Orleans County which was defined in Plate 1 of your interim report.

To date I have not had the opportunity to involve the Town of Shelby in any of my deliberations on this matter but I feel it proper that you also give the Town an adequate opportunity to respond if you have not already done so.

If I can be of any further assistance feel free to contact me.

Sincerely,

Geoffrey C Astles

Geoffrey C. Astles
Planner

GCA:d.

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NCBED-PN	Workshop for Local Officials on Tonawanda Creek Flood Damage Management

TO	FROM	DATE	CMT 1
✓FILES	P. Markham	4 May 76 Markham/ds/231	

1. Time: 12 April 1976, 1:30 p.m.

2. Place: Legislative Chambers, Genesee County building, Main and Court Streets, Batavia, NY.

3. Participants: Local officials of the county, city, village and towns located in the upstream flood plain. See Inclosure 1 for complete list of invitees and participants. Corps representatives were Don Liddell, Chief, Engineering Division; Jack Jurentkuff, Planner; Charlie Baldi, Project Manager; and Paula Markham, Public Involvement Specialist.

4. The purpose of the workshop was to describe to local officials the impacts, costs and benefits of the Batavia Reservoir Compound, and to hear their comments on the Compound proposal.

5. Don Liddell opened the meeting with a review of the various flood control measures considered by the Corps for the Tonawanda Creek watershed. He explained that some measures, e.g. Sierks and Linden reservoirs, were no longer being considered because of their high costs, limited protection and severe environmental problems. Mr. Liddell described the operation of the Batavia Reservoir Compound and then opened the meeting for comments and questions.

6. Mr. Robert Beats, Mayor of the village of Alexander, asked about protection for the village of Alexander and suggested that the Corps consider relocating the creek to the east, in the area just upstream from the Batavia Reservoir Compound, to prevent flooding and erosion damage of property along Rt. 98.

7. No serious objections to the Batavia Reservoir Compound were expressed by local officials.

8. The meeting ended at 2:30 p.m.

Paula T Markham

PAULA MARKHAM
Public Involvement Specialist

Incl
as

DA FORM 2496 — REPLACES DD FORM 96, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL ...

Persons Invited
Tonawanda Creek Workshop 12 April 1976

Lewis Del Plata	Genesee County Legislator
James Hume, Jr.	Genesee County Legislator
James Woodruff	Genesee County Legislator
Joseph Amedick, Jr.	County Highway Superintendent
Henry Mosbaugher	Genesee County SCD
Duane Ivison	Chairman, Genesee County Soil & Water Conservation District
Michael Stevens	Genesee County Department of Planning
Dwight M. Wells	Director, Genesee County Department of Planning
Raymond T. Babcock	Supervisor, Town of Batavia
	Town Clerk, Town of Batavia
Robert Smart	Town of Batavia Highway Superintendent
John O'Brien	Chairman, Batavia Town Planning Board
Ira Gates	City Administrator, City of Batavia
Roy Worthington	Supervisor, Town of Alexander
	Town Clerk, Town of Alexander
Donald Shaw	Town of Alexander Highway Superintendent
	Village Clerk, Village of Alexander
Robert Beats	Mayor, Village of Alexander
Gerald D. Post	Town Assessor, Town of Alexander
Norman Nichols	Supervisor, Town of Bethany
	Town of Bethany Highway Superintendent
William Surrey	U. S. Soil Conservation Service

Participants
Tonawanda Creek Workshop 12 April 1976

James Hume, Jr.	County Legislator
James Woodruff	County Legislator
John Carragher	County Legislator
Joseph Amedick, Jr.	County Highway Superintendent
Russ Felski	County Highway Department
Catherine Roth	Councilman, City of Batavia
Dennis Larson	City Engineer, City of Batavia
Donald Shaw	Town of Alexander Highway Superintendent
Robert Beats	Mayor, Village of Alexander
Harold Norton	Town of Bethany Highway Superintendent
William Surrey	District Conservationist, U. S. SCS
Michael Stevens	Genesee County Planning Department
John O'Brien	Town of Batavia Planning Board
Dwight Wells	Genesee County Planning Board
Henry Jawor	Erie & Niagara Counties Regional Planning Board
Gregg McAllister	Batavia Daily News

Incl 1

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NCBED-PN	Summary: Workshop for Downstream Officials on Tonawanda Creek Flood Damage Management

TO ✓FILES FROM P. Markham DATE 4 May 76 CMT 1
Markham/ds/231

1. Time: 20 April 1976, 7:30 p.m.

2. Place: Pendleton Town Hall, 6570 Campbell Blvd., Town of Pendleton.

3. Participants: Officials and planning board members from the city, towns and villages in the downstream flood-prone area. See Inclosure 1 for complete list of invitees and participants. Corps representatives were Don Liddell, Chief, Engineering Division; Jack Jurentkuff, Planner; and Paula Markham, Public Involvement Specialist.

4. Purposes of the workshop were:

a. To describe the Batavia Reservoir Compound to downstream officials and get their reactions to the plan.

b. To determine whether there is any local interest in non-structural measures that could reduce flood damages in the downstream area.

5. Don Liddell opened the workshop with a review of the various flood control measures considered by the Corps for the Tonawanda Creek Watershed. He explained why the Batavia Reservoir Compound is the most promising, and described its impacts, costs and benefits. He also mentioned floodproofing, flood-insurance, and other non-structural measures for the downstream area, but emphasized that we don't know what the Federal share of non-structural costs would be.

6. After Mr. Liddell's presentation, the meeting was opened for discussion. The following points were raised:

a. One man expressed the opinion that flooding in the lower floodlands has become worse in recent years because the creek is clogged up with brush, and asked if the Corps had considered improving drainage in the area by clearing and improving the creek channel. Mr. Liddell explained that channel ~~movement~~ improvement had been considered, but rejected as too costly and environmentally unsound.

b. Mr. Bob Floyd from the Erie and Niagara Counties Regional Planning Board said that ENCRPB was in favor of the Batavia Reservoir Compound, but would like to see additional measures incorporated into the plan to provide more protection for Erie and Niagara Counties.

c. Mr. Floyd suggested a meeting between representatives of ENCRPB and the Corps to discuss plans that ENCRPB has already developed.

d. Mr. Floyd stated that he would like the Corps to develop a topographic map showing the reduced flooding in Erie and Niagara Counties that could be expected if the Batavia Reservoir Compound were built.

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7. Local officials expressed little interest in floodproofing, flood insurance and other non-structural measures.

8. The workshop broke up into individual discussions that lasted until about 9:15 p.m.

Paula T Markham

Incl
as

PAULA MARKHAM
Public Involvement Specialist

Persons Invited
Tonawanda Creek Workshop 20 April 1976

James V. Ryan	Supervisor, Town of Tonawanda
William Wittkowsky	Mayor, City of North Tonawanda
Ferdinand Castiglione	City of North Tonawanda Planning Board
Jack Sharp	Supervisor, Town of Amherst
Clifford McDaniel	Town of Amherst Planning Board
Robert V. Maerten	Supervisor, Town of Pendleton
Joseph Bors	Town of Pendleton Planning Board
Floyd Snyder	Supervisor, Town of Lockport
Richard McFarland	Town of Lockport Planning Board
	Supervisor, Town of Clarence
Donald Smith	Town of Clarence Planning Board
George Hyder	Supervisor, Town of Newstead
Dante Marconi	Town of Newstead Planning Board
George E. Steimer, Jr.	Supervisor, Town of Royalton
Louis Gillmeister	Town of Royalton Planning Board
Charles J. Ritecz	Mayor, Village of Akron
Elmer Ottney	Village of Akron Planning Board
John McMahon	NYS Department of Environmental Conservation
Charles Brown	Erie County Planning
Robert Floyd	Erie & Niagara Counties Regional Planning Board
Larry Cartwright	Supervisor, Town of Pembroke
Chief Corbett Sundown	Tonawanda Indian Reservation

Participants
Tonawanda Creek Workshop 20 April 1976

Robert Floyd	Erie & Niagara Counties Regional Planning Board
John Krol	Town of Amherst Planning Department
Margaret Spaulding	Town of Clarence Planning Board
Lawrence Herberger	Town of Clarence Planning Board
Floyd D. Snyder	Town of Lockport Supervisor
G. B. McDowell	Town of Pendleton
Andy Johnson	Town of Pendleton
George Mason	Town of Pendleton
Joe Bors	Town of Pendleton
Bob Wurtenberger	Town of Pendleton
Burton Lenhart	Town of Pendleton
Louis Gillmeister	Town of Royalton Planning Board
Peter Buechi	NYS DEC, Buffalo